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ABBREVIATIONS.—P = Paper; D = Discussion; I = Illustrated.

Names of authors of papers, etc., are printed in *italics*.

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TIMBER-PRESERVING METHODS AND APPLIANCES.

Read before the Technical Society of the Pacific Coast, December 7, 1894.*

BY W. G. CURTIS, MEMBER OF THE SOCIETY.

THIS paper is intended less as a general review of wood-preserving appliances than as a description of a portable wood-preserving plant recently put into successful use on the Pacific System lines of the Southern Pacific Company, with a concise statement of the methods of using this plant for burnettizing ties. It presents to the Society also some brief notes on the modifications of the ordinary methods of creosoting timber, as practiced at the fixed creosoting plant in Oakland. These modifications were found necessary in order to creosote successfully Pacific Coast timbers, and they resulted in more satisfactory treatment of the timber, coupled with a decrease in the expense, as compared with ordinary methods.

The chief source of supply for railroad ties on the Pacific Coast is drawn from the California redwood timber region ; but the redwood timber, while very durable with respect to decay, is a soft timber and requires tie-plates for the best results under considerable traffic. Hence a large portion of the tie supply for Nevada, Utah, Northern California and Oregon can be most economically drawn from the pine and fir forests of Oregon and from the Sierra Nevada range in California. The supply points for this timber, however, are widely separated, the distance between the most easterly and the most northerly supply being 789 miles.

* Manuscript received May 31, 1895.—*Secretary, Ass'n of Eng. Socs.*

Intervening between these two points are high mountain ranges, the rise and fall of grades, westerly and northerly, between these two points being respectively 10,800 and 15,500 feet.

The Southern Pacific Company's experience on their Atlantic System lines, as well as the results of some experiments made in California, demonstrates the economy of treating the pine and fir ties with zinc chloride.

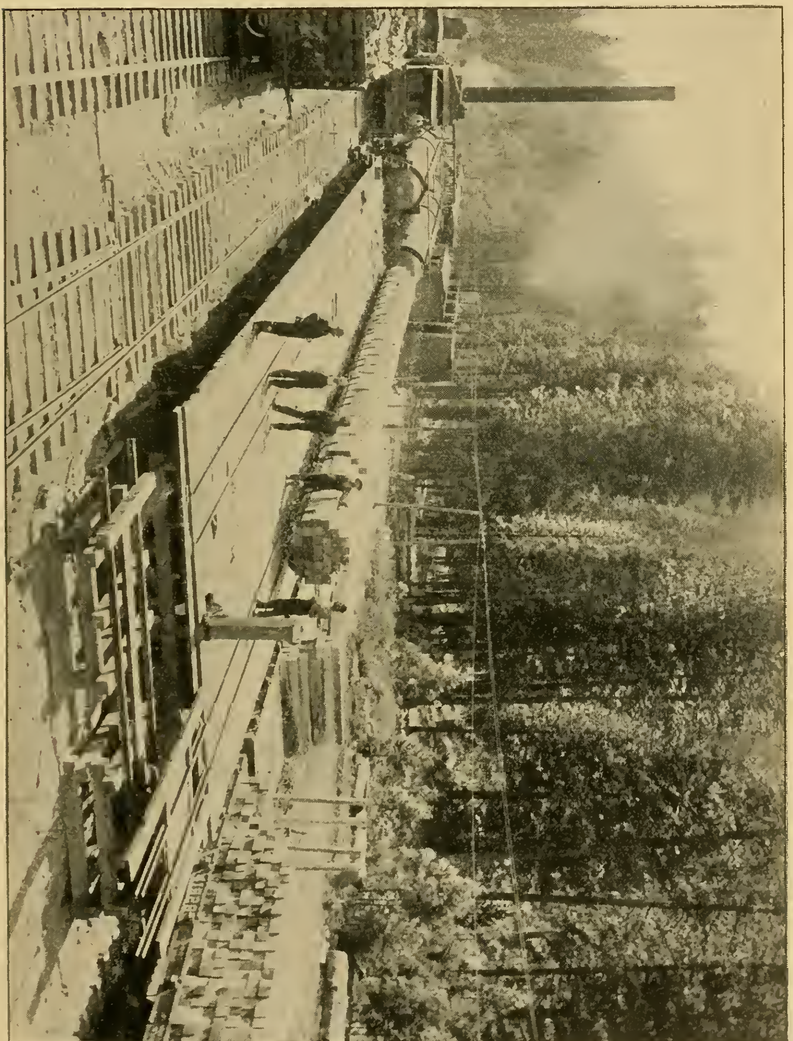
One wood-preserving plant, having a capacity for treating about 2,500 ties per twenty-four hours, is amply large to burnettize all of the ties required for the Southern Pacific lines naturally supplied with ties from the pine and fir forests. The conditions are such, however, that to locate the plant at a station, in the ordinary way, would involve a very great cost for hauling the ties from delivery points to the wood-preserving works and thence to point of use. The cost of four fixed plants, which would be required in order to reduce the cost of transportation to reasonable limits, was also prohibitory. These difficulties led to the design of a portable plant, which was put into operation in June, 1894. The photograph before you shows the plant as assembled for the treatment of ties by the burnettizing process at Chestnut Station, California.

The plant comprises all of the appliances essential for creosoting, burnettizing, and all of the ordinary wood-preserving processes; one car carrying two steam boilers, steam winch, tools, wire rope, etc., one car carrying superheater, measuring tank, force pump, air and circulating pump and condenser, two cars each carrying three wooden supply tanks for holding the preservative fluid, each tank having a capacity of 4,000 gallons, or a total capacity of 24,000 gallons, and two retorts, each six feet diameter by 114 feet long, divided into two sections, each section carried on two heavy car trucks. This plant, made up into a train of eight cars, made its initial journey from Sacramento, California, to Cornelius, Oregon, 706 miles, last May, passing over 3.3 per cent. grades and around the 14-degree curves of the Siskiyou Mountains without difficulty.

ARRANGEMENT OF TRACKS.

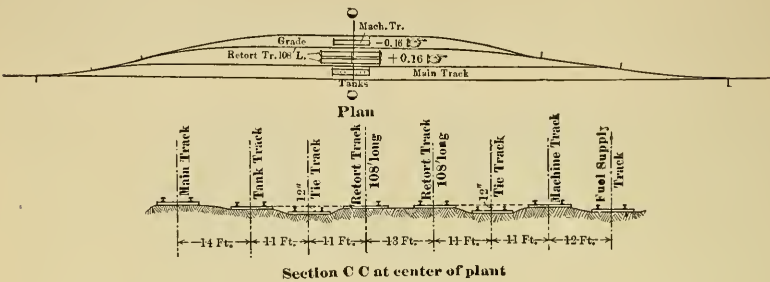
There are two arrangements of tracks used with this plant: First, when the bulk of the ties treated are for local distribution, and second, when the ties are, in the main, to be shipped to more or less distant points. In the first case, a through track is laid alongside of each retort; the tank and machinery cars are then placed on tracks beyond or outside of these tracks, ties are received on flat cars, loaded thence on the retort trucks for treatment, passed through the retorts and, on emergence at the further end of the retorts, are in position to unload on the same cars on which they were received; these flat cars having in the meantime

been moved along the through tracks, past the retorts, to their new position for receiving loads. In this plan of working, it is necessary to provide one empty flat car with every four loaded cars when received at the works, as the increased weight of ties by treatment necessitates the loading of fewer per car.



In the second case, it is not necessary to run the tracks through the works, as the ties are, in the main, received on flat cars and loaded for distribution in box cars, so that both loaded and unloaded cars are

switched in on their respective tracks, and afterwards pulled out in the direction from which the cars come.



TRACKS FOR PORTABLE PLANT.

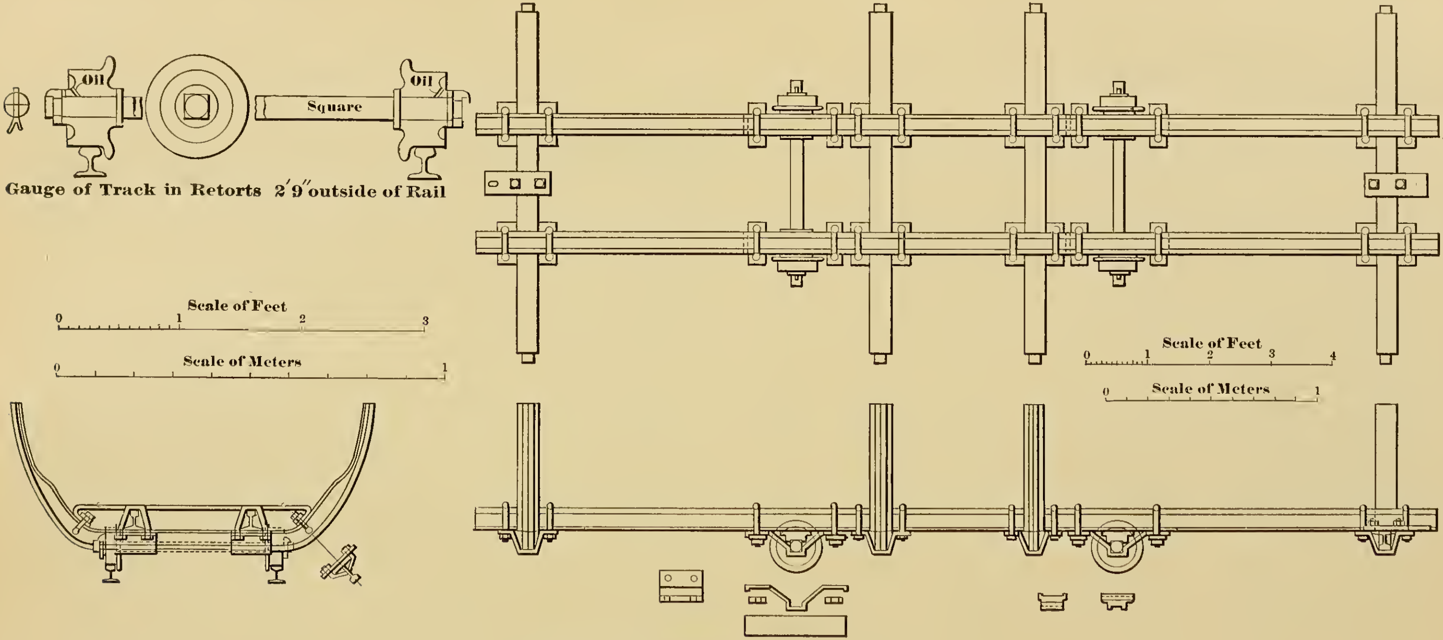
In both cases a slight grade is given to the loading and unloading tracks in such direction as is most convenient for moving the cars by hand, without necessitating the continuous use of a locomotive at the works.

SETTING UP.

The ground, tracks and foundations (made of tie blocking), having been prepared for the reception of the plant, the retorts are run into position, lined up and adjusted to height by jackscrews, which form part of the trucks supporting the retorts ; the trucks are then blocked up with steel wedges so as to take the weight off the springs, and the trucks at the center joint are blocked lengthwise. The end trucks are free to move endwise, so as to act as expansion rollers. The middle connection between the halves of each retort is then made, the tank and machinery cars are run into position and pipe connections made. All large pipe connections between machinery cars, tank cars and the retorts are made with ball and expansion joints ; the latter allow a play of some four feet, so that inequalities of track, both in height and distance, are provided for. The smokestack is raised with a gin pole and guyed ; the winch is placed in and below one of the end platforms and between the treating tracks, so that the engineer can see the charge as he works the winch. The wire cable for handling the charges is run under the platforms, from the winch to a snatch block at each end of the platforms, thence it returns on top of each platform.

PROCESS OF CHARGING AND HANDLING TIES.

The ties received at the works are placed on tracks adjoining the retort platforms, and are thence transferred directly to the retort trucks, being laid thereon in bunches cylindrical in form, bound together and to the trucks by small chains, "sticking" pieces of iron one-quarter to



Retort Trucks for Portable Plant.

three-eighths of an inch thick being placed between each layer of ties. Two ropes called "pennants" are strung under the charge. These are wire ropes having an eye in each end, and are a little longer than a charge of ties. One end of a pennant is fastened to the foremost truck and one end of the other is fastened to the hindmost truck; the back rope from the winch is fastened to the former, and the pulling rope to the latter, so that the charge is hauled into the retorts by pulling on the hindmost truck, which pushes those ahead into the retort. The object of this is to dispense with couplings between trucks, and so economize room in the retorts. As the length of the retort is about the same as that of a charge of ties (fourteen lengths), it is necessary for the engineer to place the charge quite accurately. The object of the connection with the back rope from the winch is to enable the engineer to reverse and pull the charge slightly back in case it overruns, as occasionally happens, or to stop the load accurately by braking the back line. The charge having been run into the retort, the winch lines are unhooked from the pennants, and the ends of the latter thrown under the charge. The doors of the retorts are now closed and screwed up by hand wrenches. On the first screwing up of the retorts, not much trouble is taken to get them quite tight, as this can be better done later on when the vacuum is started in the retort.

METHOD OF BURNETTIZING TREATMENT FOR RAILROAD TIES.

(1) The charge is run in and the heads or doors closed and bolted up.

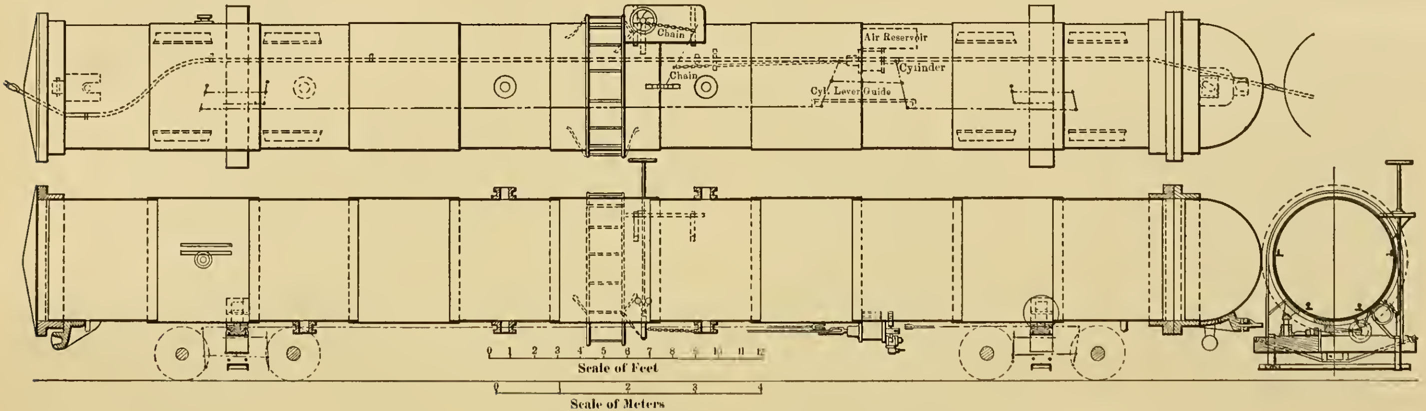
(2) A preliminary vacuum is begun; this is run up to about twenty inches. During this vacuum the doors are bolted up tightly. This vacuum process requires about ten minutes.

(3) Live steam is let in at about thirty pounds pressure, and continued for about four hours and a half. It is then blown off, requiring half an hour. During this steaming and blowing off, the retorts are drained.

(4) A second vacuum is created, of from twenty-two to twenty-six inches, which is maintained for about an hour.

(5) The retort is filled with the zinc chloride solution and pressure begun. This is continued until the required quantity of solution is injected into the ties.

(6) The surplus preservative fluid is drawn off, the doors opened, and the charge pulled out on the platform. Another charge, which has in the meantime been made ready, is immediately pulled into the same retort to undergo the same process. The treated ties are unloaded onto adjoining cars, the trucks pushed to a small transfer table at the end of the platform, transferred to the opposite track of



RETORT ON TRUCKS.

the same platform, and loaded with fresh ties to be run into the other retort for treatment.

Trucks sufficient for three charges of ties are used.

In steaming, live steam at a temperature of about 260° Fahr. is used, corresponding to a gauge pressure of about 20 pounds. Preservative fluid is injected at a temperature of about 150° Fahr. A maximum pressure of about 140 pounds is allowed in injection; with freshly cut ties, however, 120 pounds is not usually exceeded.

The total time of treatment averages about 8½ hours, and as the retorts are run nearly alternately, we get from noon one day to noon the following day five charges treated, or a total of 2,520 ties, 7 inches by 8 inches by 8 feet, per day of twenty-four hours If, however, all the ties are new or freshly cut, the time is reduced so as to get out six charges per day, or 3,024 ties in all per day of twenty-four hours.

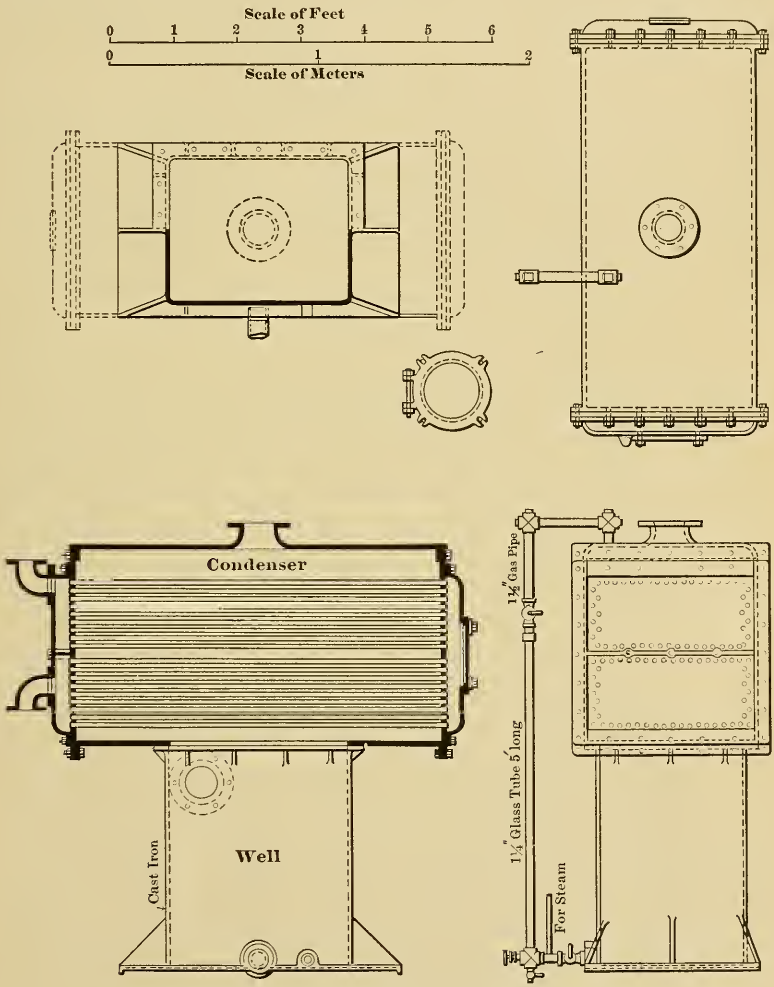
We find the time required varies greatly with the kind of timber and with the time during which the ties have been seasoning. California mountain pine, fir and spruce require less time than Oregon fir, and all timbers are more readily treated when freshly cut. An Oregon fir tie, seasoned in the air for two years, will take double the time for the treatment required for one freshly cut. Occasionally a close-grained, well-seasoned tie will not receive the preservative at all, the fluid penetrating into the sides only about half an inch.

Much attention has been given in this plant to providing means of watching the effect of the various steps in the process, so as to vary the treatment as the timber requires it. The retorts are provided with thermometers, the steam pipes with a pyrometer, and all tanks with gauges; the condenser is provided with a measuring well, all injection is from a gauged measuring tank, and sample ties are tested and reported from each batch, as noted further on. The principal blanks used for this and other reports are appended hereto.

The condensing apparatus consists of one set of ordinary surface condensers (connected to the vacuum pipe and between the retorts and air-pump), which is over and supported upon a measuring well, into which all condensed saps and vapors flow, thus preserving a constant surface for condensation. The measuring well is provided with a glass gauge, and is of such dimensions that each foot of the glass gauge represents one-fourth of a pound of water extracted per cubic foot of timber. This well is so arranged that it can be emptied without stopping the air-pump. By this means any desired dryness of the timber may be accomplished with certainty. In the practical operation for the treatment of ties the extraction of moisture is stopped when the rate, as shown by the condenser gauge, is reduced to one pound of water per cubic foot per hour.

MIXING THE FLUID FOR USE.

Concentrated solution of zinc chloride, called "stock solution," as formerly purchased and now manufactured at the works, consists of about 43 per cent. pure zinc chloride, 2 per cent. of impurities (iron, aluminium, lead, etc.), and 55 per cent. of water. This is weighed out



SURFACE CONDENSER FOR PORTABLE PLANT.

and mixed in a small sump, with a proper proportion of water, thence pumped into the wooden supply tanks, tested with a Beaumé hydrometer, and, if necessary, a slight addition of either stock or water added, so that the liquid for use, called "standard solution," registers $2\frac{1}{2}°$

Beaumé at 60° Fahr. The theoretical proportions for the desired standard solution, containing $1\frac{7}{10}$ per cent. pure zinc chloride, are 34.46 pounds stock of 43 per cent. zinc chloride to 100 gallons of pure water; but as there is much evaporation during the process the tendency of the standard solution is always to get stronger, so that, on a continuous run, there is added a certain proportion of water to allow for evaporation, or, what is the same thing, the quantity of zinc chloride to the gallon of water is reduced. Experience has taught us that about 27 pounds of zinc chloride stock solution per hundred gallons of water will keep our reserve solution (amount always in the supply tanks), together with that added for daily consumption, up to standard; but this is carefully watched and additions made one way or the other, as the case demands, so that the standard, when injected into the ties, is always $1\frac{7}{10}$ per cent. strong. The standard solution is heated to 156° Fahr. by turning steam through coils in bottom of tanks before being pumped into the charge.

TESTING TIES.

At intervals during the regular progress of the work and whenever any charge shows some change in the treatment as to necessary vacuum, time or amount of pressure, and after each change in kind, quality or dryness of timber, four sample ties are taken from a charge consisting of ties of average grain, one heaviest, one lightest and two average weight, and each tie is bored in the middle of its width and length with a one-inch bit. The first half inch of borings is thrown away, after which each inch of borings is preserved separately and designated as one inch, two inch, and three inch specimens. Each specimen is burned to an ash, over a gasoline jet, in a porcelain roasting dish, in contact with the air. The ashes are carefully collected in a platinum cup, distilled water added, with a slight excess of hydro-chloric acid, converting the zinc oxide into zinc chloride. It is then filtered into a test tube and the zinc hydrate thrown down with sodium carbonate, making a white flocculent precipitate. The liquid is then made up with distilled water to three drachms. The resulting milky liquid is compared with standard liquids in tubes of the same size as the test tubes, each tube containing three drachms. The standard liquids are graded to represent 6, 9, 12, 15, 18, 21 and 24 one-hundredths of a pound of zinc chloride per cubic foot of timber. As shown by the annexed table of proportionate parts (for which, as well as for much of the other data in this paper, I am indebted to our fellow-member, Mr. J. D. Isaacs, who has designed most all of the details of the plant and devised many improvements in the method of operation), the maximum of zinc chloride, per cubic foot of timber, desired is 24 one-hundredths of a pound. We are so certain of what we are doing by our methods

of observation that the tests are principally of value as checks. Recent tests have sometimes shown a minimum of 21 one-hundredths, but usually indicate the full amount. It is to be recollected that this minimum is from the geometric center of the tie. In such cases specimens taken nearer the ends show prescribed quantity. After boring, the ties are plugged with creosoted sticks turned to a tight fit, and shipped for use with the rest.

RECORDS.

A tabular record of each charge, giving all dates, times, durations, pressures and temperatures, is kept and charges numbered; a similar tabular record of all tests is kept and duplicates forwarded to headquarters. All ties are stamped on the ends, with the month and year of treatment.

We have found it economical and convenient to manufacture our own chloride of zinc stock solution. The apparatus is simple and inexpensive, and requires little attention. It consists of three lines of barrels arranged in steps. Beginning with the top and numbering them 1, 2, 3, 4, 5, and 6, they are arranged as follows:

No. 1, bottom 3 inches above top of No. 2, and has a lead spout emptying from the bottom into the top of No. 2.

No. 2, bottom 12 inches above bottom of No. 3, and has a lead pipe from near bottom to top of No. 3.

No. 3, bottom 6 inches above bottom of No. 4, and has a lead spout from near bottom to top of No. 4.

Nos. 4 and 5 same as No. 3, each emptying in same way into that below.

Each barrel is charged with about 600 pounds of zinc.

The carboys of muriatic acid are lifted to a platform beside barrel No. 1, through which the acid trickles rapidly, taking off, so to speak, its wire edge; that is, preventing violent action in barrel No. 2. In barrel No. 2 some ebullition takes place. The heavier, partially formed chloride sinks to the bottom, passes up through the lead pipe, and over into No. 3 and so on. We found it necessary to raise barrel No. 2 higher than the rest of the series, in order to get head for flow through its discharge pipe, some of the head being lost by the upward action of the hydrogen gas and steam. A continuous stream of zinc chloride, completely saturated as to the acid, runs from the pipe of No. 5, but to make certain, we run through No. 6; thence into storage barrels standing ready for use. The capacity of the chemical plant is about 5,000 pounds of stock solution per ten hours.

After each carboy of acid is emptied, one-eighth of its weight in water is thrown into barrel No. 1, which has the effect of cooling the

zinc, keeping down somewhat the ebullition in barrel No. 2, and supplying water evaporated. The loss of chlorine by evaporation is about one per cent. We find a better result by this process than by allowing the acid to simply stand on the zinc. The resulting zinc chloride stock solution has a density of 50° Beaume′, and contains 43 per cent. of zinc chloride.

CREOSOTING, OR IMPREGNATION OF TIMBER WITH DEAD OIL OF COAL TAR.

The portable plant is arranged for creosoting timber also. This requires only the additional adjuncts of a superheater and steam coils in the retorts. Although we treat sawn timber with creosote, the bulk of the timber treated is in the form of round piles of Oregon fir. This material proved to be extremely difficult of treatment by any of the standard methods. The temperatures and pressures had to be forced, and the time required was very long (32 to 38 hours) to get any effective penetration. The piles after treatment were badly split and checked, and their strength seriously impaired.

In November, 1891, some experiments were undertaken with a view to overcoming these objectionable results. These experiments lead up to our present standard creosoting process, which closely corresponds with the methods advocated by Boulton ten years or more ago.

We merely boil the timber in the dead oil, and when sufficiently dry, inject the oil by pressure. In effect, we have returned to the open vat process tried fifty years ago, plus pressure in a closed retort. An open vat for boiling, followed by the introduction of the timber into a closed receptacle for injection, would answer the same purpose, but we find it more convenient to perform both parts of the process in the same retorts. In this process we use no vacuum, but pass the vapors during boiling through the surface condenser, leaving the outlet from the latter open to the air. The object in using a condenser is to enable us to measure the sap extracted from the timber, and to recover the lighter portions of the creosote carried over with the vapors of sap. Every foot in the measuring well of the condenser corresponds to ½ pound of water, or sap, per cubic foot of piles treated for average loads, and we find that the piles are practically dry when the condenser gauge shows 6 inches per hour. The same precautions as in burnettizing are used to follow the characteristics of each load and to vary the treatment accordingly.

The result of these changes in treatment has been most satisfactory. The time has been cut down to 12 to 14 hours per charge, as against our former time of 32 to 38 hours, and as against that required in present Eastern practice of 22 to 27 hours. Temperatures are reduced from 280° Fahr. to 240°; pressure reduced from 200 pounds to 120

pounds; fuel about one-half formerly used per charge. The timber is practically uninjured by the treatment. It is less checked than in ordinary air-seasoned timber, and whatever checking takes place is during the boiling, so that all checks are well filled with creosote.

In common with timber in burnettizing, the greener the wood is, the more easily it is impregnated with creosote. No difficulty is experienced in securing any desired penetration.

MEMORANDUM OF EXPERIENCE WITH TREATED AND UNTREATED TIES.

The treatment of ties with preservative substances was commenced in Europe as early as 1838, perhaps earlier. Of the many and various materials treated with on a large scale, only about four seem to have been used to any considerable extent. These were sulphate of copper, bi-chloride of mercury, chloride of zinc and creosote oil, and of these four only two seem to have survived for general use; namely, chloride of zinc and creosote. The former, on account of its comparative cheapness, is the one most commonly used.

The average results of tie preservation in Germany, where perhaps more careful records have been kept and investigations made than elsewhere, indicate that the life of railroad ties (so far as decay is concerned) is almost exactly doubled by preserving them.

In November, 1889, a small number of burnettized ties were put in the track, in a gravelly clay roadbed, near Tucson, Arizona, and an inspection just made, after four years and eleven months of service, shows that all of these burnettized ties are perfectly sound. At the same time and place, various untreated ties were put in the track adjoining the burnettized ties; of these, Truckee white fir has decayed to a depth of about ¼ of an inch on the under side; Truckee yellow pine has decayed to a depth of from 1 to 3 inches on the under side; Truckee red fir ½ inch decayed on under side; Truckee tamarack and Truckee sugar pine decayed from 1½ to 3 inches on under side; Shasta white fir and white yellow pine decayed on under side from 1 to 4 inches; Shasta red fir decayed on under side to a depth of from 1 to 2 inches; Shasta sugar pine decayed on under side to a depth of from 1½ to 2½ inches. The redwood ties, laid without tie-plates, under 50-pound rail, are perfectly sound, but the rail has cut down into them from 1 to 2 inches, indicating that the maximum life for such ties in such localities is between five and six years.

In December, 1889, some burnettized ties were laid in the San Joaquin Valley, near Turlock station, in a roadbed composed of sandy loam, under 60-pound rail. An inspection made March 1, 1894, after three years and four months of service, shows a slight decay on the

under side. Of the ties of similar timber, but untreated, put in the track at the same time the burnettized ties were laid, and adjoining them, the white and red fir were completely decayed and removed from the track in August, 1893, after three years and nine months of service. Of the yellow pine untreated ties, 90 per cent. were removed from the track after three years and nine months of service. Of the sugar pine, untreated, 90 per cent. were rotted down to the danger point and removed from the track after three years and four months of service. The tamarack, red and white fir, yellow pine and sugar pine, from the eastern slopes of the Sierras, near Truckee, untreated, are more or less badly decayed, after three years and four months of service, the indications being that the maximum life of the best of them will fall somewhere between four and five years. Of the 6 in. x 8 in. x 8 ft. redwood ties put in at the same time with very small tie-plates, all are sound after five years of service; the plates, which were entirely too small, have bent up considerably, but have not cut down into the ties more than $\frac{3}{16}$ of an inch. The 6 in. x 8 in. x 8 ft. redwood ties that were laid without tie-plates at the same time, are cut down under the rail to a depth of two inches, leaving only four inches of sound wood under the rail, and were removed from the track after about three years and nine months of service.

The service life of ordinary redwood ties (which, in ordinary road-beds, will last many years without failure by decay), is measured not by time, but by the volume of tonnage passing over the rails; the speed as well as the weight being a factor in the wear in some proportion not well ascertained. Under average conditions of traffic, redwood ties eight inches wide and six inches thick, laid about 3,000 to the mile of track, and supporting 60-pound steel rail, will endure about 13,000,000 tons of cars and engines passing over the track; this amount of traffic being equal to nearly 30,000 trains, each consisting of a locomotive and tender weighing sixty tons, and fifteen cars weighing between 375 and 400 tons, or say an average of about sixteen trains with a locomotive and fifteen cars each per day for five years. The average endurance of 7 in. x 8 in. redwood ties is probably somewhere between 17,000,000 and 18,000,000 tons of traffic. Redwood ties are usually condemned as unserviceable when crushed down so as not to leave more than four inches of sound wood under the rail.

SOUTHERN PACIFIC COMPANY.

(Pacific System.)

WOOD PRESERVING WORKS.

Report of . . . . creosoted at . . . . , 189 .

Retort.		A.	B.	A.	B.
Charge number					
Date going in					
Date coming out					
Time . . .	Load in at				
	Filling begun at				
	Bath begun at				
	Refilling begun at				
	Pressure begun at				
	Pressure left off at				
	Load out at				
	Total time				
Temperature	When filled				
	At end of bath				
	When refilled				
	At end of pressure				
	When oil is let out				
	Of superheated steam				
Pressure . .	At beginning				
	At end				
Condensation	Per hour at beginning of bath .				
	Per hour at end of bath				
Pressure oil taken from					
Inches pumped from measuring tank					
Pile numbers inclusive					
Cubic feet timber					

(Signed)

Superintendent.

SOUTHERN PACIFIC COMPANY.

(Pacific System.)

WOOD PRESERVING WORKS..

Report of . . . . burnettized at . . . . , 189 .

Retort.		A.	B.	A.	B.
Charge number					
Date going in					
Date going out					
Time . . .	Load in at				
	Vacuum begun at				
	Live steam begun at				
	Vacuum begun at				
	Filling begun at				
	Pressure begun at				
	Pressure let off at				
	Load out at				
	Total time				
Temperature	At end of live steam				
	When filled				
	At end of pressure				
	When solution is let off				
Pressure . .	At beginning				
	At end				
Inches pumped from measuring tank*					
Number of ties in charge					
Number of cubic feet in charge					

* Each inch = 25 gallons.

(Signed)

Superintendent.

SOUTHERN PACIFIC COMPANY.

(Pacific System.)

Wood Preserving Works.

Report of Inspection of Creosoted Piles and Timber made at . . . . , 189

The following creosoted piles (or timbers) have been inspected this day and passed or rejected as per statement below:

Piles.

No. of Pile.	Penetration.		Length of Pile.	Shipped in Car No.	Remarks.
	Butt.	Tip.			

Timber.

No. of Pieces.	Size.	Feet B. M.	Minimum Penetration.	Shipped in Car No.	Remarks.

Instructions.—Inspect for penetration by boring two ½-inch holes at a distance of from 10 to 15 feet from each end, according to length of stick; the two holes near each end to be diametrically opposite, and the pair on one end to be at right angles to that on the other. In special cases other holes may be bored. Care must be taken not to bore into a check. After inspection the holes must be plugged with wood saturated with creosote and turned to a driving fit.

SOUTHERN PACIFIC COMPANY.

(Pacific System.)

Wood Preserving Works.

Report of tests of burnettized ties made at . . . . , 189

		Heavy.	Light.	Medium.	Medium.
Charge number.					
Tie number.					
Thickness of tie.					
Width "					
Length "					
Weight of "					
Zinc chloride per cu. ft.	Specimen 1 tie.				
	" 2 "				
	" 3 "				

(Signed)

Superintendent.

BURNETTIZING—TABLE OF PROPORTIONAL PARTS—October, 1894.

Gallons Standard Solution	$= 1\frac{7}{10}$ per cent. $ZnCl_2$	1.	2.984	6.94	14.492	13.038	12.979	4.144	4.5	5.25	1.686
Pounds Stock "	= 43 " "	0.335	1.	2.326	4.856	4.369	4.349	1.389	1.508	1.759	0.565
" Pure Zinc Chloride	$= ZnCl_2$	0.144	0.43	1.	2.088	1.879	1.87	0.597	0.648	0.757	0.243
" " Metallic Zinc	= Zn	0.069	0.206	0.479	1.	0.9	0.896	0.286	0.311	0.362	0.116
" Zinc Dross or Skimmings	= 90 per cent. Zn	0.077	0.229	0.532	1.111	1.	0.995	0.318	0.345	0.403	0.129
" Pure Hydrochloric Acid Gas	= HCl	0.077	0.23	0.536	1.118	1.006	1.	0.32	0.347	0.405	0.13
" Commercial Muriatic Acid	= 32 per cent. HCl	0.241	0.719	1.675	3.494	3.144	3.125	1.	1.086	1.267	0.407
Number of Ties 6″ x 8″ x 8′		0.222	0.663	1.542	3.22	2.897	2.884	0.921	1.	1.165	0.375
" " " 7″ x 8″ x 8′		0.19	0.568	1.321	2.759	2.482	2.471	0.789	0.858	1.	0.321
Cubic Feet of Timber		0.593	1.768	4.112	8.587	7.725	7.591	2.455	$2\frac{2}{3}$	$3\frac{1}{9}$	1.

Standard Solution.	$2\frac{1}{2}°$ Beaumé.	$1\frac{7}{10}$ p. c. Zinc Chloride.	1.017 Spec. Grav.	8.472 Weight per Gallon.	14,000 Gall. Reserve.

DISCUSSION.

Dr. Meyers.—Have any evil effects been noticed from cattle licking the ties and being poisoned by the zinc chloride?

Mr. Curtis.—I have never heard of any difficulty of that kind either from creosote or zinc chloride. In the mercury process there is a great deal of difficulty of this kind. It greatly affected the men employed. All sorts of expedients were resorted to in order to overcome it. They dressed in rubber clothes. And then, when laid in place, it was poisonous to animals.

Mr. Wagoner.—What takes place immediately after the vacuum has been made; does the sap run out of the ties?

Mr. Isaacs.—But very little sap comes out of the wood in the first vacuum. The principal object of the first vacuum is to get the air out of the retort so as to facilitate the introduction of steam, and also to enable us to close the doors tightly. It is hard to get the doors very tight unless there is a pressure of the air on the outside.

Dr. Meyers.—Do the borings show uniform impregnation clear to the center? How much zinc chloride is used per tie?

Mr. Isaacs.—For thorough impregnation of 7 x 8 x 8 inch ties there is required for the whole tie 0.75 pound of pure chloride of zinc. The impregnation is uniform clear to the center.

Dr. Meyers.—What is your experience with creosote in getting it uniformly distributed through the wood? In Germany they succeeded in forcing it clear through the wood, but the distribution was not uniform, and there were certain parts of the wood that would contain no creosote.

Mr. Curtis.—We do not seek to get the creosote clear through the wood. We are satisfied with a thorough impregnation in the outer part of the wood. But it is important that all the wood should be thoroughly seasoned and completely dried out. Our tests show a penetration of about three-quarters of an inch around the stick. From our experience thus far, this amount of impregnation seems to be quite ample to protect the timbers against the attacks of marine creatures. We have to be careful in treating the piles not to have them split and crack. A party came to us and spoke about a cluster of piles at the end of Clay Street wharf, and said the limnoria were eating them all up. We had the Harbor Commissioners pull one of the piles up and laid on the

wharf. I struck it with an ordinary hatchet and it split into two pieces the whole length. It had been cracked in the retort, but there was no evidence whatever of its being touched by the teredo or the limnoria.

Dr. Meyers.—Has your experience indicated any tendency for spikes to draw out of the wood on curves?

Mr. Curtis.—We have had no trouble of that kind. Our experience with preserved wood does not exceed five years, and our experiments have been on a rather small scale. It is the practice on our American roads to use tie-plates on curves, which overcomes that difficulty. Double-spiking the tie on the outer side is another expedient. Just what effect zinc chloride has on a spike, in the way of corrosion, I do not know.

Mr. Isaacs.—The effect of zinc chloride on metals is to form a rust, but it seems to stop after it gets a little ways. We have experimented with almost every kind of paint in our retorts to prevent it, but without any success. A coating of rust will form about the thickness of a sheet of paper, and that is the end of it. It stays there until the plant is removed, and dries out, and then this coating is knocked off. When we use the retort again another coating will form. But we do not have any serious trouble from this source.

Mr. Wagoner.—Where do you purchase the creosote, and where is it made?

Mr. Curtis.—What we use is brought from England. We have experimented with American creosote, but the latter is not near as good as the former. To be efficient it has to be of a certain standard, and the American creosote is not near up to the specifications. It should contain not less than eight per cent. of tar acid, which seems to be sufficient to coagulate the sap in the wood, and twenty-five per cent. of heavy oil. The heavy oil seems to be a very necessary part; it gets into the wood and corks it up, so to speak; it completely fills up the wood.

Prof. Wing.—Have you any items as to the economy of using treated ties?

Mr. Curtis.—For pine ties it is about this way: In Oregon we buy them as low as 20 or 21 cents; in Northern California about 26 cents. All the evidence goes to show that by burnettizing them we can at least double their life. This process is now costing about 8 cents, and we expect to get it down as low as 7 cents for ties 7 x 8 x 8. So you see this is a good economic arrangement.

Mr. Vischer.—What is the relative cost of creosoting and burnettizing?

Mr. Curtis.—Creosoting is a great deal more expensive. The cost is pretty near ten to one for the wood actually treated, but there is not the amount of penetration in creosoting. We boil the wood in creosote oil until we have extracted pretty nearly all the moisture out of it—we cook it out, and then it is pretty well sterilized. Then we put this protection of creosote all around it—plug it up by the heavy oils, so the germs are not carried in by contact with the air or the water. If, on the contrary, the timber is not well seasoned before creosoting, and if the moisture is not thoroughly out of it, we have found quite a number of instances where the interior is completely rotted out, leaving a sound shell of creosoted wood around the outside. From our experience, if the work is thoroughly done, we believe piles will last a long time. They are protected and will last something in the same way as timbers in a covered bridge or in a house; they are protected against air and water.

Mr. Vischer.—The two processes of treatment are used for quite different purposes?

Mr Curtis.—Yes sir. We use creosote for piles, and for most of our timber work. We use it for everything in trestles up to the stringers, and sometimes creosote the stringers.

Mr. Wagoner.—Does not creosoting make the timbers more combustible?

Mr. Curtis.—I think it does. However, we have had nearly ten years' experience on the Atlantic system, but we do not know of a single fire that can be attributed to the fact that the timbers had been creosoted.

While I think of it, I will mention that common salt is a great preservative of wood. We have a stretch of track twelve miles long between Wadsworth and Ogden laid on bottom land on the edge of the great Salt Lake. The ground is soft, and there is a good deal of salt in it. The ties there are as bright and fresh as when they came out of the tree twenty-six years ago. Salt is very cheap on the Colorado desert; all we have to do in some places is to just shovel it up. There is a great deal of timber on the east of the desert, and we have been experimenting with jacketing the timber; making a hole all around the stick, and tamping salt in it. It requires renewal after every rainy season. We expect some very satisfactory results.

Mr. Vischer.—In the burnettizing process, what is the effect on the wood? Is the action of the chemicals purely astringent or is there a

filling up of the pores producing additional hardness due to the foreign matter?

Mr. Curtis.—I think it is partly a filling up and not purely an astringent action.

Mr. Isaacs.—The wood becomes a little more hard and a little more brittle. The tie is not quite so strong as before, but it is not sufficiently weakened to injure its service.

President Grunsky.—I am informed that Dr. Meyers has the results of some experiments in the vulcanizing process. We would be pleased to hear from him upon that subject.

Dr. Meyers.—In order to understand the vulcanizing process I think we must look at it from a chemical standpoint. The object of the process is to produce a change in the natural composition of the wood itself, instead of forcing antiseptic matter into it. Wood in its natural state is strongly antiseptic; it contains creosote, tannin, albumen, etc.; about sixty different chemicals in all. By the action of heat its natural constituents are changed. It produces changes in the pores of the wood, and a chemical change in the sap itself. In that process we endeavor to keep the large antiseptic qualities originally in the wood. We heat the wood to 200 and 300 degrees Fahrenheit, and maintain a pressure of about 150 pounds to the inch. The treatment takes from eight to twelve hours, depending upon the condition of the timber, and upon the timber itself. Dry, compressed, superheated air is circulated through it, and after the air becomes saturated with moisture, it is taken out and then reheated and passed through again. In that way considerable moisture is extracted from the wood. After the wood has undergone treatment its chemical composition is entirely different.

This experiment was tried in the East over ten years ago. At that time several hundred ties were placed on the elevated roads in New York City, in company with other ties that were not treated. I had the privilege of examining the treated ties about a year ago, and they were still doing good service, while the untreated ties, the Road Master told me, had rotted away and been removed.

The tests to which Prof. Wing refers are tests of strength, I believe. I know the process has been accused of weakening the wood, on account of the amount of heat used. Out of curiosity I made some tests at Columbia College of the strength of different kinds of woods after it had been vulcanized, and in its natural state before it was vulcanized, taking each piece from the same stick. The first test was made on Norway pine. It broke under a load of 3,000 pounds. It was placed on supports seven feet apart, and the pressure placed upon the center. The same piece untreated supported 2,680 pounds. That shows an increase

in strength of 11.94 per cent. Cypress broke under a load of 2,600 pounds; untreated, under a load of 1,860 pounds, an increase in strength of 39.8 per cent. I believe that cypress showed the greatest increase of strength.

Treated spruce broke under a load of 2,780 pounds, and untreated under 2,460 pounds; an increase in strength of a little over 13 per cent. Bass wood when treated supported a load of 2,840 pounds, and untreated 2,560 pounds; an increase of 10.9 per cent.

After that a larger number of tests were made, and in every case there was an added increase in strength.

Mr. Curtis.—Have you any figures as to the cost of the vulcanizing process?

Dr. Meyers.—I do not remember them. I know they had a great deal of timber to treat, more than they could take care of. I think they have two plants now, and are also building one in Washington. It is a patented process. It is rather new, and has been more experimental than otherwise. I think it is very much in its favor that the Manhattan Elevated road treats every piece of timber it uses on the road. That fact more than anything else led me to take an interest in it. Col. Hunt told me that they had tried every other process, and they had found this the most satisfactory.

Mr. Wagoner.—Have any experiments been made where the wood came in contact with the soil? Of course these ties were used on elevated structures.

Dr. Meyers.—They tried it in different kinds of soil. I know of a certain tunnel just out of New York City, where wood decays very rapidly, and said to be the worst place on the road for timber. They put in some treated timber from the South, which they said in its natural state was useless for railway construction, and it proved to be about as good as any wood. It seems to make a durable article out of an otherwise uselesss thing. I examined these ties myself, after they had been in the ground for six years. They still retained a strong odor of the wood, and were in very good condition.

The pieces that I tested as to strength were cut, I think, by the Bell Telephone Company, and were in the shape used for cross-poles. We simply cut them in two halves lengthwise; one piece we treated, and the other did not.

Mr. Isaacs.—There is one point in regard to creosoting that I think has some bearing on this vulcanizing process. Our theory is to first coagulate the albumen of the wood by heat, and then inject the creosote. Creosote contains carbolic acid, and other substances. During this process a filtration takes place. The carbolic acid goes in first, and that is followed by napthaline, which is of itself a pretty good anti-

septic, and is permanent. If we used carbolic acid and nothing else, in a short time the piles would be no longer preserved. This filtration keeps the heavy oils near the surface, and forms an exterior coat which is impervious to water, and prevents the washing out of the napthaline and the coagulated albumen. It seems to me that one of the difficulties in this vulcanizing process is lack of sufficient material to form wood creosote. The use of wood creosote, by the way, has never been a success. There is sufficient material in the wood to form a good wood creosote for the timber, or tie, but it is not in the right place—that is to say, the heavy portions, the napthaline portions, and the other constituents are all mixed up together. As far as we have investigated, our arrangement of these materials is about right for the purpose intended.

Dr. Meyers.—What is the temperature of the creosoting process?

Mr. Isaacs.—About 250 degrees. I have tried 350 degrees without apparently injuring the wood at all, but not with pressure.

Mr. Vischer.—The impression seems to prevail among the men using the ordinary kiln-drying process with redwood, that it is an easy matter to use too much heat, and thereby make the wood brittle.

Dr. Meyers.—It seems that under a very high pressure the wood does not seem to burn ; it seems to prevent ignition. It seems it would be an easy matter to heat the wood without the presence of creosote first, without the pressure of air.

Mr. Isaacs.—We found if we heated it without creosoting, it took a long time to dry. If a vacuum is formed to help the drying you deprive the timber of any means of getting heat except radiated heat.

Dr. Meyers.—In the vulcanizing process they use pressure.

Mr. Wagoner.—What purpose does the pressure serve?

Dr. Meyers.—Pressure seems to make the chemical change in the wood caused by heat more uniform through the wood ; it also seems to prevent the liquids from escaping, and keeps them more in a liquid form instead of a gaseous form. I have often wondered if it was not the mere heating of the wood that preserved it ; just as in boiling an egg, the boiling coagulates the albumen and preserves it.

Mr. Curtis.—The present difficulty in heating wood, if the air surrounds it, is a tendency to check the wood and split it.

Mr. Wagoner.—I should say the pressure was to prevent evaporation.

Mr. Isaacs.—The pressure is to keep the moisture in the wood while this process is going on.

COST OF STEAM AND WATER POWER IN MONTANA.

Read before the Montana Society of Civil Engineers, June 8, 1895.*

By M. S. Parker, Member of the Society, and of the American Society of Civil Engineers.

The rapid development of mechanical appliances for the usage of electrical energy is working a wonderful revolution in the motive power of the world. The controlling of steam for motive power is the result of modern investigation, almost within the memory of the oldest inhabitant. Close upon the heels of this discovery and its development to the full limit of perfection, comes this newly discovered motive power, electricity, and with each day are born new ideas, almost inspired ideas, one might say, suggesting more improved methods for controlling this mysterious, unanalyzed, irresistible, powerful agent. Who can predict what the next century will bring forth in the use of this mysterious fluid? Judging from the progress of investigation for the past quarter of this century, the result will far exceed the most visionary views of the present enthusiasts. Engineers are aware of the progress being made in the generation and transmission of electricity for power purposes. The civil engineer is not generally an electrician, on the contrary, his knowledge is more general than special. The civil and electrical engineers, however, are closely allied, and must, in the future, work hand in hand together. The electrical transmission for power is fast bringing all the hitherto obscure water powers of the world into commercial importance. The day is not far distant when all the available water power of the United States, in fact, of the world, will be utilized to its fullest capacity.

I need not go into detail as to progress being made in this direction. This is known to all engineers who are keeping abreast of the times.

Montana has extensive opportunities for the development of water power within her borders, and the next decade should show vast strides along the lines of its development.

The writer has given much attention during the past five years to the opportunities for developing water power in Montana, particularly along the course of the Missouri River, and must admit that the possibilities are beyond his most sanguine expectations, both as to cost and quantity of power. The development at Great Falls, Montana, with which the writer has been connected since its inception, is but in its infancy. There is no reason why, in the near future, every town and mining camp in Montana should not have its electric power station supplying all

* Manuscript received July 17, 1895.—*Secretary, Ass'n of Eng. Socs.*

power for lights, street railways, and the running of machinery for all purposes. In the opinion of the writer, steam must give way to electricity, and that soon, especially in Montana, the State ranking first in the country for its available water power. Its cheapness alone will force the result. Coal consumers' boilers will have to give way to water wheels. The percentage of loss in transmission I will not go into in detail in this paper, sufficient to say that the percentage of loss in electrical transmission, within twenty miles of distance, is not greater than the ordinary loss by direct rope transmission from power station to works, 1,000 feet distant. Late-long distance transmission of electricity for power experiments are highly satisfactory. The object of this paper is simply to lay before the Society a few tables prepared by the writer showing relative cost of steam power as compared with water power in Montana. Such data is constantly needed by the engineer, and it is a duty that one owes to the profession to record whatever may be of interest to its members. The following tables will explain themselves:

TABLE NO. 1.

Compound Engine.—All Steam Charged to Power.

Table showing ordinary running daily and yearly expenses 500 H. P. Plant.

Cost of Coal per long ton 2240 lbs.		Pounds of coal per H. P. per hour.	Cost of coal per H. P. per day.	Boiler attendance per H. P. per day.	Engine attendance per H. P. per day.	Oil waste and supplies per H. P. per day.	Total daily expense 1 H. P.	Total yearly expense, 365 days, 1 H. P.
			Cents.	Cents.	Cents.	Cents.	Cents.	
$1.75	10¼ hours per day	5.6	4.48	0.6	0.75	0.3	6.13	$22.37
	24 " " "	5.6	10.47	1.54	1.50	0.7	14.21	51.86
$2.00	10¼ " " "	5.6	5.17	0.6	0.75	0.3	6.82	24.89
	24 " " "	5.6	12.09	1.54	1.50	0.7	15.83	57.78
$3.00	10¼ " " "	5.6	7.46	0.6	0.75	0.3	9.11	33.25
	24 " " "	5.6	16.47	1.54	1.50	0.7	20.21	73.76
$4.00	10¼ " " "	5.6	10.33	0.6	0.75	0.3	11.98	42.93
	24 " " "	5.6	24.19	1.54	1.50	0.7	27.93	101.94

This table is based on the consumption of Sand Coulee, Montana, *slack coal*, tested at the Silver Smelter at Great Falls, Montana, on twenty-four hour-run purposely, without extra precaution, to ascertain amount of coal consumed, using three-quarter-inch grate bars, 60 x 16 feet tubular boilers. Result: $5\frac{6}{10}$ lbs. per hour per horse-power. A 200-horse-power compound engine at Silver Smelter costs $64 per horse-power per year, as I was informed by an engineer who made the estimate two or three years since. I think the figures about right for present conditions. The smaller the horse-power of the plant the larger the expense per horse-power proportionately.

TABLE No. 2.

500 H. P. PLANT.

SHOWING COST OF STEAM PLANT PER H. P. TO CHARGE TO POWER.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Engine Compound. All Steam charged to Power.	Engine and Piping.	Engine House.	Engine Foundation.		Total Cost Engine Plant.	Depreciation, 4 per cent.	Repairs, 2 per cent.	Interest, 8 per cent.	Taxation, 1½ per ct. ¾ Cost.	Insurance, 0.5 per cent.	Total, Columns 7, 8, 9, 10 and 11.	Boiler Complete.	Boiler House.	Chimneys and Flues.	Total Cost, Boiler Plant.	Depreciation, 5 per cent.	Repairs, 2 per cent.	Interest, 8 per cent.	Taxation, 1½ per ct. ¾ Cost.	Insurance, 0.5 per cent.	Totals of Columns 17, 18, 19, 20 and 21.	Total Yearly Expenses. Columns 12 and 22.
	$25 00	$8.00	$7.00		$40.00	$1.60	$0.80	$3.20	$0.45	$1.65	$7.70	$9.33	$2.92	$6.11	$18.36	$0.918	$0 367	$1.468	$0.207	$0.092	$3.052	$10.752

This table is to be used in connection with Table No. 1. Add the total in last column ($10.752) to total as shown in Table No. 1 for the total yearly expense of one horse-power on 500 H. P. plant. Columns 6 and 16, Table No. 2, give cost of plant per H. P. ($40.00 + $18.36 = $58.36). The prices on which table is based, *i. e.*, Great Falls, Mont., prices, are applicable closely to all parts of Montana.

TABLE No. 3.

Showing Yearly Expense of Water Power per H. P. on Wheel Shaft.

HORSE-POWER.	1	2	3	4	5	6		
	Original Cost.	Interest on Original Cost—8 per cent.	Tax, 1½ per cent. ¾ Cost.	Depreciation, 2 per cent.	Repairs, 2 per cent.	24 Hours per Day. Total Running Expenses per H. P.	Totals of Columns 2, 3, 4, 5 and 6.	Totals of Fixed Charges.
3,636 net H. P. . . .	$52.00	$4.16	$0.78	$1.04	$1.04	$.255	$9.57	$34.796
7,200 net H. P. . . .	35.00	2.80	0.525	0.70	0.70	2.55	7.27½	52.370

The above table is arranged from the writer's note-book. Number of horse-power and cost from actual verified estimates in two instances that the writer has planned.

In conclusion it may not be amiss to mention some of the noted water-powers of the country, giving their capacity and charges for power:

Holyoke, Mass., ...	12,260	H. P.	Gross Power
Manchester, N. H., ...	12,000	"	"
Lowell, Mass., ...	11,845	"	"
Lewiston, Maine, ...	11,000	"	"
Lawrence, Mass., ...	10,900	"	"
Cohoes, N. Y., ...	6,560	"	"
Minneapolis, Minn., ...	9,200	"	"
Great Falls, Mont., ...			
Black Eagle Falls, ...	18,200	"	"
Niagara Falls, ...	100,000	"	"

These amounts are closely the minimum figures for power—gross horse-power. The net power is about 20 per cent. less on the wheel shaft.

Various charges for water-power at Manchester, Lowell, Lawrence, Minneapolis; a few places from the above list are as follows: Manchester, about $300.00 per mill power for original purchase, $2.00 per day for surplus per mill power. Lowell, about $300.00 per mill power for original purchase, $2.00 per day per mill power during back water, $4.00 per day per mill power for surplus under 40 per cent., $10.00 per day per mill power over 40 per cent. and under 50 per cent., $20.00 per day per mill power for surplus over 50 per cent., $75.00 per day per mill power for any excess over limitation, 100 per cent. Lawrence, about $300.00 per mill power for original purchase, and about $1,200 for new

leases per mill power. At the above-named places a mill power is equivalent to 65 horse-power on the wheel shaft. The charges for surplus water in the before-mentioned instances amounts to about the same thing at the different places. At Minneapolis, a more modern water-power, the mill power is equivalent to 50 horse-power on the wheel shaft and is charged for at the rate of $1,200 per mill power. The charges for power at all the above-mentioned places is about the same for new leases, and amounts to nearly $25.00 per horse-power per year for 24-hour runs. I learn that the Niagara Power Company has leased power in large amounts as low as $8.00 per horse-power per year in 5,000 horse-power leases. The Eastern powers are based upon ten hours per day run.

The surplus is the accumulation of water in storage pond, enabling the extra running of wheels. With the figures for cost of steam power at hand it is a simple calculation to determine as to the worth of water-power. The original cost of development of the power together with the resulting power, determines its commercial value as compared with steam.

WOODEN BRIDGE CONSTRUCTION ON THE BOSTON AND MAINE RAILROAD.

Read before the Boston Society of Civil Engineers, May 15, 1895.*

BY J. PARKER SNOW, MEMBER OF THE SOCIETY.†

THE subject of iron and steel bridges has been quite extensively written up in our technical literature during recent years, but wooden bridges are seldom discussed, and when mentioned, are generally treated as temporary structures or excuses offered for their use. The building of such bridges is, however, a live business on the Boston and Maine Railroad, although the impression seems to be prevalent in many quarters that such construction is obsolete and out of fashion.

This paper is offered to describe the present practice in wooden bridge construction on the above-named railroad, and if not considered as in line with present approved practice elsewhere, may at least have some interest as a history of one branch of the bridge-building art.

On the system operated by the Boston and Maine there are 1,085 wooden bridges of all kinds in a total of 1,561. This number covers overhead as well as track bridges and includes everything of 6 feet clear opening and upwards, except stone box culverts. The proportion of wooden bridges grows less each year, although more than half of the new structures built to replace old bridges are built of wood.

The types most commonly used for new work are pile trestles, plain stringer bridges, compound stringers made of timbers keyed together to get greater depth than is possible with single sticks, pony trusses of the Queen post and Howe type, and Town lattice bridges. At the present prices of iron bridges Howe trusses of considerable span, if built in first-class shape of Southern pine timber, cost almost exactly the same as iron ones and consequently are practically ruled out. A considerable number of stringers trussed with rods beneath are in existence, but are seldom built at the present time.

Spruce timber is used for all parts of Town lattice bridges, and for caps, stringers and ties in many trestles and plain stringer bridges on Northern lines. On lines south of Central New Hampshire, however, Southern pine is almost invariably used. Spruce is sufficiently durable when roofed in, and on account of its lightness is much better than Southern pine for lattice trusses, but its softness and tendency to warp and the difficulty in getting sticks of sufficient length make it unsuited for Howe truss work of magnitude. For bottom chords of lattice bridges

* Manuscript received June 4, 1895.—*Secretary, Ass'n of Eng. Socs.*

† This paper was printed in the JOURNAL for June, 1895, but with some of the matter transposed. It is accordingly reprinted here.—*Secretary, Ass'n of Eng. Socs.*

of over 100 feet span, recourse must be had to Southern pine also on account of the difficulty in getting spruce of the requisite length. Tamarack, oak and chestnut are used for piles in trestles.

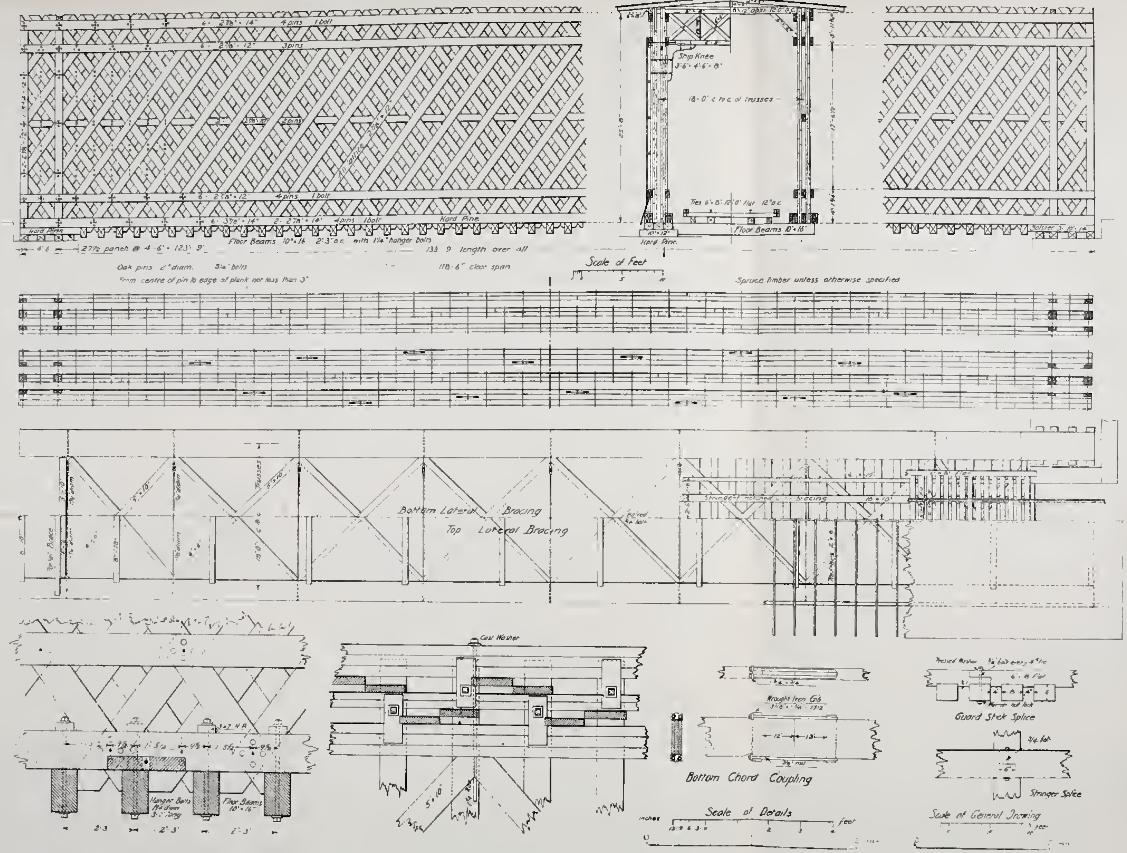
The life of sawed spruce exposed to the weather is but about six or seven years. Southern long-leaf pine of prime quality in similar conditions is reliable for twelve to fourteen years. When covered in and well ventilated and kept free from accumulations of dirt, either timber will last forty to fifty years. Sawed chestnut for ties, stringers, etc., is about intermediate in durability between spruce and hard pine. It has been used for bridge timber on the Southern lines of the system considerably in years past, but is not so used now and is not recommended.

Tamarack piles in dry land trestles will last eight to ten years, chestnut and oak of good quality fifteen to twenty.

The loads used in calculating new wooden bridges are somewhat lighter than the standard used for those of iron. It is thought that wooden bridges are necessarily of a less permanent character than iron ones and that within their natural life the weight of rolling stock will not increase so much above what it is at present as may occur in the life of an iron bridge; again, if wooden bridges are found to be too light for future loads, they can be strengthened, or supported on trestle bents much better than iron ones, and a wooden bridge, like a piece of masonry, will give abundant notice of distress before it will fail entirely. The governing reason for building wooden bridges instead of iron ones altogether is, of course, their less first cost, and if the full standard load for iron bridges was used in designing them this element of advantage would be reduced and they would be no more serviceable or satisfactory for present use than if designed for thc lighter load. The load used is a train of consolidation engines weighing, each, with tender, 172,000 pounds, with 24,000 pounds on each driving axle, or 80,000 pounds on two axles, seven feet apart. This is somewhat in excess of engines in use at present on this system, and although considerably lighter than the load used in designing iron bridges, the considerations given above seem sufficient to justify its use.

The usual unit strains used are, for Southern pine 1,000 pounds per square inch direct tension and 800 compression; the latter, of course, reduced for ratio of length to diameter. For spruce this unit is taken at 650 compression and 800 tension. For fiber strain in stringers and beams the unit is 1,200 pounds per square inch for both hard pine and spruce. The reason for adopting this figure for spruce is that in exposed situations, as is the case with stringers, the life of spruce is so short that it is a waste of material to provide for the much talked about increase in engine loads, and while sound, this unit gives a very satisfactory bridge. For combined transverse and longitudinal strain two-thirds of the former is added to the latter and 800 pounds used as the unit. Longitudinal shear-

J. PARKER SNOW, WOODEN BRIDGE CONSTRUCTION ON BOSTON AND MAINE R. R.



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ing is kept below 80 pounds per inch and transverse crushing on hard pine from 350 to 400 pounds per square inch, depending on whether the whole width of the stick is covered or only a small area.

These unit strains are used for new work; an old bridge will, however, stand up and carry its load when the computed strains in some parts are very high. Of the three classes of bridges built twenty years ago, iron pin, iron riveted and wooden, all of which figure equally near the danger limit, common prudence will select the pin bridge as the first one to be removed, the riveted one next and the wooden one, if sound, last.

The cost of bridges for single track of 120 feet span will compare something as follows:—Iron $5,300. Howe truss of Southern pine and iron angle blocks $5,000, and spruce lattice $3,500. Below this span, the advantage of wooden bridges over iron ones in point of cost will increase and above it the advantage rapidly reduces to nothing.

The standard spacing of bents in pile trestle bridges is 15 feet. Solid caps drift-bolted to the piles and girder caps with riders are used indiscriminately, the former being the cheaper and the latter making the most rigid structure. The stringers used on these trestles are for single track, two 8″ x 16″ under each rail and one of the same dimensions on each side placed 10 feet apart from outside to outside. The stringer sticks are 30 feet long, laid to break joints; the two sticks under each rail are spaced 2″ apart by cast iron spool separators and ¾″ bolts, four at each cap. The stringers are secured to the caps by drift bolts. The floor consists of ties 6″ x 8″ x 12 feet long, laid 4″ apart in the clear. Tie spacers 6″ x 8″ are placed flat on the ends of these, notched down one inch and bolted to every fourth tie. These bolts have a round burr washer under the head on top and a Warren nutlock for washer at the lower end. The floor is kept in line by occasional lining spikes or drift bolts through the ties into the side stringer.

The tie floor above described is standard for all wooden bridges; it is shown in cross-section Fig. 1. In designing, the ties are considered as

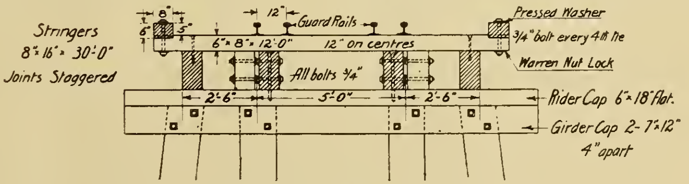


FIG. 1. STANDARD TRESTLE; 15 FT. BENT.

distributing the load so that 80 per cent. is carried by the main stringers and 20 per cent. by the side ones. The continuity of the stringer sticks over two spans is considered as reducing the moment of the load at the centre of span by 10 to 12 per cent.

Plain stringer bridges are built the same as above described for trestles, except as the stringers do not have the advantage of continuity over supports, the sections must be larger for similar spans. The depths of the sticks should not be less than $\frac{1}{12}$ to $\frac{1}{14}$ the span.

When the span becomes too great for merchantable depths of timber, or convenient thicknesses, recourse is had to keyed stringers. These are made by placing one stick on top of another and framing cast-iron keys between them, as shown in Fig. 2. A vertical bolt at each key prevents the timbers from separating.

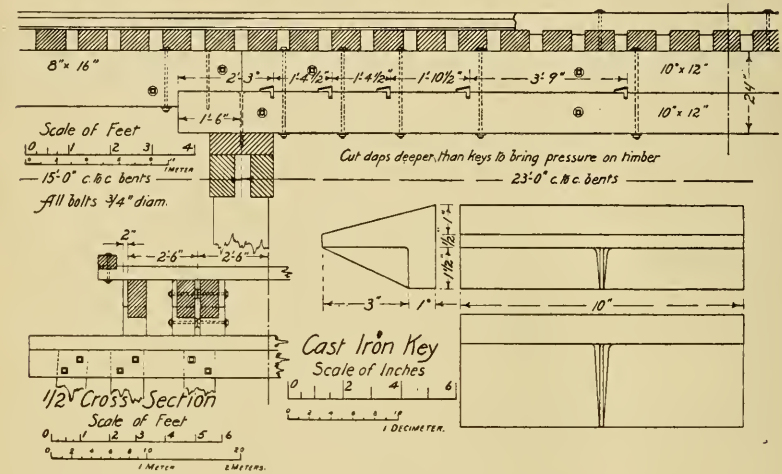


Fig. 2.

These keys are proportioned for the longitudinal shear, and hence the total depth of the compound stick can be used in computing its moment of resistance. The keys are cut $1\frac{1}{2}''$ into each upper and lower stick, and an attempt is made to distribute them according to the intensity of the shearing strain; but near the ends of the stringer a strict adherence to this requirement would bring them so near together in some cases that the daps might split out. With notches $1\frac{1}{2}''$ deep, it is desirable that they should be at least 18″ apart. The quantity of longitudinal shear at the neutral axis, between any point and the end of a beam, is a function of the fiber strain at that point; being equal to $\frac{b.d.f.}{4}$ when $b.$ is the breadth, $d.$ the depth and $f.$ the extreme fiber strain. A convenient way to locate the position of the keys is to draw a line the ordinates of which represent the moment of the load and lay off to some convenient scale, $\frac{b.d.f.}{4}$ as an inclined ordinate at the center of this curve. Now, beginning at the base, space off on this inclined line the value

of each key, and draw horizontals through the points of division; these horizontals will cut the moment curve into spaces showing the proper field for each key. The friction between the two sticks, induced by the load and by the grip of the vertical bolts, helps to resist the longitudinal shear, and a proper proportion can be added to the value of the key when spacing off the inclined ordinate.

These stringers require considerably more material than trusses of equal strength, but the labor on them is small and they can be put in place and prepared for the passage of trains in much less time than trusses. This latter quality is of great importance, and should be given more attention by bridge designers than it generally receives. This style of bridge works in with the ordinary trestle spans very conveniently when it is desired to make a wide opening for a runway for ice or logs, or for a highway underpass. The lower stick of the compound stringer is extended beyond the upper one to furnish a seat for the regular stringers of adjacent bents. In cases, too, where the trestle bents are high and expensive it will lessen the cost of the structure to make alternate spans compound or keyed stringers. This style of bridge is available up to clear spans of 30 feet.

Pony trusses are used for spans between 30 and 60 feet, generally of the Howe type. For overhead highway bridges requiring trusses modified pony Howe trusses are used almost exclusively. For these latter and for track bridges it is altogether better to use floor beams, distributed along the chord about $2\frac{1}{2}$ feet apart, rather than to concentrate the load at panel points by means of stringers carrying the load to large floor beams, as is done in iron bridges, and it is generally best to hang the floor beams below the chord. If the plank floor of highway bridges is laid directly on these cross floor beams it brings the plank parallel to the line of travel; this is considered objectionable, and hence longitudinal spiking joist or stringers, 4 to 6 inches thick, are laid on the cross floor beams and the plank spiked to these. On bridges carrying light traffic a single 3″ floor is used, but where the travel is heavy it is economical to use a double floor, generally 2″ below and 3″ for wearing surface. The under plank lengthens the life of the floor very considerably by keeping it safe for a long time after the corners of the upper plank have worn through.

Railroad bridges of this class should always have the top chords stayed against side motion, as shown in Fig. 3, and it pays to protect the trusses from the weather by sheathing and roofing them in.

For spans greater than is desirable for pony trusses the Town lattice built mostly of spruce is our only resource. As before stated, Howe trusses of Southern pine cost almost as much as iron bridges at present prices. Spruce, the only available timber growing in the region in

which these bridges are used, is not well adapted to Howe truss work, but is excellent for lattice bridges. This style of bridge seems never to have been developed to much extent outside of New England, and it is fre-

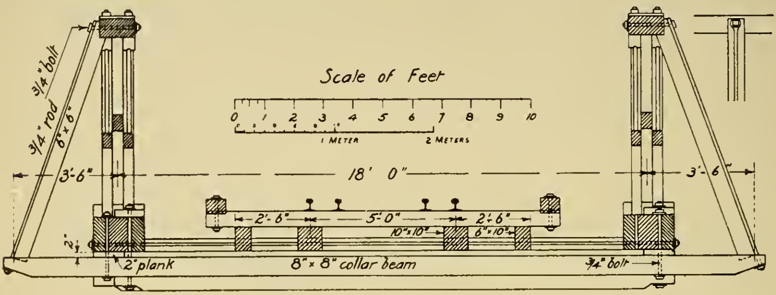


FIG. 3. SWAY BRACING FOR PONY TRUSSES.

quently referred to as peculiarly unscientific and wasteful of timber. It is, however, the best of the purely wooden bridges, and its present survival here and its economy over all other types disproves its wastefulness. These trusses should always be built double, that is, with two webs like a box girder. Single web trusses can be made strong enough up to 80 feet span, but they do not stand so steadily or keep in line so well as those with double webs. The distance between the webs is immaterial, but is generally made equal to the thickness of two chord plank, from 6 to 8 inches. Outside of the webs, it is not deemed advisable to use more than three thicknesses of plank on each side; this confines the chord to 8 planks, and as this is generally not sufficient to give the requisite strength, a second chord is added at the second web intersection. These second chords serve not only to carry chord strain, but also to stiffen the diagonals and to assist the outer chords to distribute the shear between the tension and compression members of the web.

The chord strength of these trusses is computed by assuming the distance between the centers of outer chords as the effective strain depth of the truss, and reducing the section of the inner chords in the ratio of the squares of their distances from the neutral axis. In the case shown on the inset this ratio would be nine-sixteenths. In several bridges of this type now standing on the Boston and Maine road, built in former years, there are three sets of chords, but the third chord has but little theoretical value, and judging by the amount that the joints are pulled they assist but little in carrying the chord strain. The proper arrangement of the breaks in the planks of the lower chord affects the strength of the whole much the same as the arrangement of eyebars affects the strength of pins in an iron bridge.

In bridges of 125 feet span and upwards it becomes necessary to fasten the abutting ends of the chord plank together and the device

shown on the inset is used for this purpose. The gib-bars are wrought iron, varying in section with the thickness and width of plank to be joined; hexagon nuts are used on the yoke rods so as to necessitate as little cutting of the chord stick as possible. A ribbon is sometimes put between the webs at the middle height of the truss, as shown in the inset, with the idea of stiffening the web and preventing vibration.

The shear is assumed to be uniformly distributed over all the web planks cut in a given section. The members are so thoroughly pinned together that they cannot possibly act as single independent systems to be separately calculated as is advocated in some text-books, but the strain must be equalized throughout a vertical section much as would be the case with a solid web.

A lattice truss should extend well on to the masonry. For reasons connected with the proper construction of the floor this extension on the abutment should be about one and one-half panels; a solid bolster should be placed under the chord for this distance and under this should be the cross wall blocking. The compression diagonals near the end of the truss deliver their shear to very short tension members; the fastenings of these do not seem to be able to carry the load delivered to them, and the bolster is needed to help take the thrust of the compression members direct. Many old bridges built probably without much knowledge where the maximum shear occurs have failed by having the bottom chord split down or literally sheared at the edge of the wall plate by this action. Proper bolsters would have largely prevented this. It is the custom now to put solid posts between the webs at the end and second panel points extending the whole depth of the truss. These cut through the two middle plank of the chords and would endanger shearing the bottom chord if the bolster did not extend beyond the cut-off. These solid posts furnish a substantial support to pin the short ties to and to receive the compression members which do not reach the bottom chord. None of the trusses built in this way have shown indications of weakness in the way explained above. The panels should be between 4 feet and 4½ feet and the web plank should be given inclinations of nearly 60° with the horizontal.

The pins used in these bridges are 2″ oak. They should be of well-seasoned timber, and should be carefully turned so as to drive tightly when the bridge is erected. Much depends on the pins. In old and weak bridges the pins are frequently found much distorted. In heavy trusses all plank must be at least 12″ wide in order to take four pins at the chord intersections. At the web crosses two only are used. At all chord intersections and some in the web a ¾ bolt is used to hold the plank firmly together. This bolt is deemed of great importance from its preventing the plank from opening, which would greatly increase the

leverage on the pins. It is possible that iron pins perhaps of heavy pipe rather than solid bars would mark an advance over the present practice, but they have not yet been tried so far as the writer is aware.

The floor beams in these bridges are at present invariably hung below the chord, two beams per panel. The ends of the web plank projecting below the chord are cut into to allow space for each floor beam. They are hung by bolts passing through the open spaces in the chord and through washer blocks on top of same.

The lateral bracing is the Howe system, that for the lower chord being laid directly on top of the floor beams, and the stringers cut over it; 5″ by 8″ to 12″ is the size generally used. The main stringers under the rail are 10″ by 10″ and the side stringers 6″ by 10″.

The load used for floor beams is 5,500 pounds per lineal foot of track, which is assumed to cover both the live and dead loads. Eighty per cent. of this is assumed to be on the main stringers and 20 per cent. on the side ones. The clear width in these bridges is 15 feet. This makes the effective length of floor beams 18 feet or more and calls for sticks so large that it is best to use Southern pine for them. Spruce can be readily obtained of sufficient size, but when so large and in so exposed a situation it twists and checks badly. Southern pine is used also for bottom chord plank for spans greater than 100 feet, and should always be used for bolsters and wall plates. The stone parapets of all through wooden bridges are brought in so as to be flush with the face of the abutment (see inset). This serves to protect the timber floor from the weather, obviates the large amount of blocking needed on the stonework when it is not so done, and shortens the bridge floor.

Lattice bridges are built on the Boston & Maine Railroad as above described up to 150 feet clear span. They are, however, rather unwieldy at this length and it is preferred for spans above 125 feet to build them with an arch inserted between the webs. These arches are built up to the required section with 2″ or 3″ plank and bolted to the trusses at every lattice cross which comes in contact with the arch. They abut against the stonework below the lower chord on large Southern pine skew-backs scribed to the stone. The skew-backs are mortised out in steps to receive the square ends of the planks. The planks of the arches are well spiked when laid and radial bolts are freely used to bind them well together. The load is brought upon the arch by vertical rods passing through the arch and down through the lower chords and floor beams.

The arch is proportioned to carry its own weight and the whole live load on the bridge. The trusses are made of the same section as those of one half the span which have no arch. These compound bridges are very satisfactory, being rigid under traffic and of more pleasing appearance than when built without arches. They are also much more econo-

mical of timber than simple trusses for the reason that the arch uses timber wholly in compression, in which condition the entire section is available; whereas when timber is called upon to act in tension a large portion of the section must be wasted in making the connection.

In order to secure a satisfactory track surface after several years' use, there must be considerable camber framed into lattice bridges. For trusses without arches, there should be 1″ for each 25′ of span and for those with arches 1″ for about 37½′ of span.

The lattice bridge has been described thus at length, partly because it has not been so fully treated as other styles in technical literature, and because it is the only kind that can be built in competition with iron at present prices. On the Boston & Maine system, there are many Howe and Pratt bridges, a few Burr, Briggs and Child's trusses and many of mongrel type; but the Town lattice has a large plurality over any other kind and there seems to be ample and good reasons for its natural survival.

These bridges as built to-day are, in all their important details, direct descendants of, and very near kin to, those built in years past by the bridge carpenters of Northern and Central New England. Those built by David Hazelton and his men furnish the basis of the present practice on this road and although they were built without engineering advice, they bear analysis well, with the possible exception of the bottom chords.

It has come within the observation of the writer many times that when an intelligent master-carpenter has had the care for a term of years of a line of wooden bridges covering any given style of truss, he gradually brings their parts, when building new ones, to almost the exact size called for by scientific analysis when actual loads are used in calculation. He will use iron rods that are too small for they show him no distress unless they break, but the timber parts guide him to right results.

It is this property of a timber bridge, its certainty of giving warning of approaching weakness, that has kept the record of wooden truss bridges so clear from fatal disasters. It is not reasonably safe to use a light iron bridge until it is worn out, but a wooden one may be used till its deterioration is rapidly approaching the end. Neither is it safe to entrust light iron bridges wholly to the care of workmen not technically educated; the timber parts of wooden ones may be.

It is no part of the intention of this paper to advocate building wooden bridges instead of properly designed iron ones, but rather to describe the favorite styles now used on those parts of the Boston & Maine Railroad where wooden bridges prevail, and to show that these styles are not so obsolete as seems to be supposed in some quarters.

DISCUSSION.

Mr. B. W. Guppy.—The Town lattice truss was patented in 1820 or 1821. The inventor, Mr. Ithiel Town, published pamphlets in 1821 and 1831, describing the bridge, and the claims that he makes therein as to the economy and durability of this type of bridge have been fully substantiated. Copies of these pamphlets are in the possession of the Boston Public Library.

Some of the advantages that Mr. Town claimed for his bridge are as follows:

"Suitable timber can be easily procured and sawed at common mills, as it requires no large or long timber.

"Defects in timber may be discovered and wet and dry rot prevented much more easily than could be in large timber.

"There is no iron-work required, which at best is not safe, especially in frosty weather."

This last statement is rather amusing, as Mr. Town previously states that the trusses can be built either of wood or iron. Moreover, it is due to a free use of iron that the present development of the bridge has been obtained.

Iron is used principally in the form of bolts and rods, and its use increases the strength of certain parts like the tension chord, and allows of adjustments to take up the shrinkage of the timber.

Wedges at the ends of the pins or treenails were used to keep the sticks in close contact. Bolts at the intersections of chords and lattice are now used for the same purpose, and they also add to the strength of the chord connections.

Iron chord couplings add a large percentage to the strength of the tension chord.

A Howe truss system of lateral bracing is used instead of the Burr system originally adopted, and by means of turnbuckles on the rods placed so as to be easy of access, adjustments can be made to keep the trusses properly in line.

Formerly the floor beams in through bridges rested on top of the bottom chord, bringing most of the load on the inside chord sticks and web system. The present practice is to hang the floor beams below the bottom chord by hanger bolts alternately on opposite sides of the chord, as shown on the drawing accompanying Mr. Snow's paper. This distributes the load equally between the two web systems and adds an amount to the headroom equal to the depth of the chord plus the depth of the floor beam.

Some of these bridges have a very long life. One that was taken down on the Boston and Maine system last year and replaced by a simi-

lar structure was claimed to be over fifty years old, although no exact record could be found. This refers to the trusses. The floor was newer, having been renewed and strengthened. The timber was in fairly good condition, extreme lightness of construction being the principal cause for renewal.

Another bridge taken down the year before was over forty-five years old.

In use these bridges stand a great deal of abuse. A butting collision on the approach to one bridge piled the cars of one train up through the roof. Beyond breaking a hole in the roof, and cutting up a few ties, no damage was done to the bridge. Another collision in which only one train participated, the bridge acting as a buffer, resulted in considerable damage to the end vertical and web; but the bridge is still in use without any repairs and is considered to be perfectly safe. In another case logs at high water broke off the ends of the lattice. Bolts were put in connecting the floor beams with the upper lower chord, relieving the lower joints of all vertical load, and as they are still strong enough to transmit the chord stress, the bridge is used without any apprehension of danger. This bridge has the floor beams resting on top of the bottom chord. If they had been hung below they would have protected the ends of the lattice.

During the recent floods in New Hampshire, a pier was washed out from under a two-span bridge. As the invariable practice is to make these bridges continuous over all intermediate supports, the bridge was saved.

At the same time the abutment was washed out under the end of another bridge, causing one of the trusses to settle several feet. It was blocked up into place and is now in use, the flexibility of the construction preventing any serious damage.

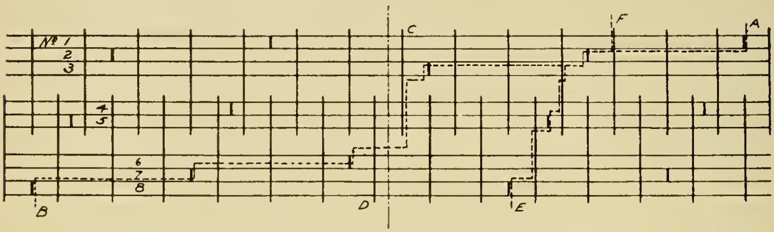
Fire is the principal enemy of these bridges, but the danger has become much less since the introduction of coal burning engines. The fires usually start in the roof and are generally extinguished before they do any damage to the trusses. A good coat of white-wash together with water barrels, buckets and a ladder at each bridge are the means of protection.

The road has these bridges insured, but as fatal fires are so few, and the losses are generally so small, it would seem to be economy to have the road do its own insuring.

In designing this truss, the practice is to use a panel length of from four feet to four feet six inches, the panel length being the distance between the chord pinnings for one of the lattice systems. The pinnings of the second lattice system are half way between those of the first. This brings the distance between two pinnings equal to one half a panel

length. The panel length is taken at such a length within the limits given as will bring the total number of panels equal to $n + \frac{1}{2}$ where n is any integer. This arrangement brings the center line of truss half-way between two pinnings, making the chord stick cuts symmetrical, and making the odd length sticks the same at both ends.

The method of arranging the cuts in an eight-chord stick is shown in the accompanying diagram.



In figuring the strength of the tension chord, the following assumptions are made:

(1) When there are four pins and one bolt at a pinning, the net area of the stick is taken as the depth in inches minus five, multiplied by the width.

(2) The value of a pinning to transmit stress between two sticks is taken as 1,100 pounds for each pin and 600 pounds for one bolt, making a total of 5,000 pounds for one pinning of four pins and one bolt.

These values were arrived at by figuring the pin for bearing, shearing and bending; the limiting value being given by the strength of the pin to resist bending. The lever arm was taken a constant of 1.3 inches for the three thicknesses of plank generally used, namely $2\frac{7}{8}$, $3\frac{3}{8}$, $3\frac{7}{8}$, as the flexibility of the pin must cause the load to be concentrated near the inner edge of the stick and the examination of pins taken from old bridges seems to justify this assumption.

When wrought iron chord couplings are used, the strength of a coupling is the net value of four $\frac{7}{8}$-inch rods at 10,000 pounds per square inch, or 16,920 pounds.

When chord couplings are used, there are two cases to consider: (1) when the strength of one coupling plus three pinnings is less than the net strength of the stick, and (2), when it is greater.

In the second case, the weakest center section is practically straight across the chord on the line $C\,D$. In the first case, the minimum value of chord is along the line $A\ B$. There is also a section $E\ F$, $1\frac{3}{4}$ panels from the center, the strength of which should be investigated, as in some cases it has a less value than the center section.

In the bridge shown in the drawing, the bottom chord is composed

of six 14 x $3\frac{7}{8}$-inch sticks and two 14-inch x $2\frac{7}{8}$ sticks. Net value of one 14 x $3\frac{7}{8}$ = 9 x $3\frac{7}{8}$ x 1000 = 34,875 pounds.

One coupling = 16,920 pounds,
Three pinnings = 15,000 "

31,920 " which is less than net stick and the minimum center section will be along the line *A B*.

Stick 1	1 coupling	3 pinnings	31,920
" 2	1 "	3 "	31,920
" 3	1 "		16,920
" 4	net stick	14 x $2\frac{7}{8}$	25,875
" 5	"	"	25,875
" 6	1 coupling	1 pinning	21,920
" 7	1 "	3 pinnings	31,920
" 8	1 "	3 "	31,920
			218,270 lbs. net value of center section.

Section $1\frac{3}{4}$ panels from center

Stick 1	1 coupling	3 pinnings	31,920
" 2	1 "	1 pinning	21,920
" 3	net stick	14 x $3\frac{7}{8}$	34,875
" 4	"	14 x $2\frac{7}{8}$	25,875
" 5	1 pinning		5,000
" 6	net stick		34,875
" 7	net stick		34,875
" 8	1 coupling		16,920
			206,260 lbs. net strength of chord $1\frac{3}{4}$ panels from center.

With sticks 16 inches deep and the same widths the center section will have a value of 229,770 pounds, and the other section 235,260 pounds, being the greater in this case. Inspection shows that the strength of the center section is increased only by the increase in sticks 4 and 5.

This span is about the limit of this style of bridge without the use of an arch, although spans have been built up to 150 feet.

THE ENGINEERING HISTORY OF A LAW SUIT RESPECTING A CONTRACT FOR RAILROAD BUILDING IN SOUTH DAKOTA.

Read before the Boston Society of Civil Engineers, June 12, 1895.

By Francis C. Tucker, Member of the Society.

On April 7, 1890, a written contract was entered into for the construction (not including bridges and track) of 103 miles of the Grand Island & Wyoming Central Railroad, extending from the Cheyenne River, near Edgemont, to Kirk, near Deadwood,—through the heart of the Black Hills of South Dakota. May 15, 1890, ten miles of this (not consecutive) were sub-let by oral contract to a firm of sub-contractors, and August 21st following, this contract was reduced to writing, the sub-contractors obligating themselves to fully complete the railroad (excepting bridges and track) on or before October 30, 1890. Grading began May 24, 1890, but was not entirely finished until about January 24, 1891—nearly three months later than the limit of time named in the contract. About one month after completion of grading the final estimates were sent, duly checked and certified by the Resident Engineer, to the Chief Engineer, who, having satisfied himself as to their accuracy, duly rendered to the principal contractors a statement of the same final quantities, and they in turn sent a statement of them to the sub-contractors.

Approximate monthly estimates were made regularly during the progress of the work. The sub-contractors were dissatisfied with these, and had their work remeasured and re-classified immediately on completion by F. S. Mitchell, of St. Louis, and J. E. Thomes, of Kansas City. These engineers had a profile of the work, but not the cross-section notes. The total quantities of earthwork returned by them were 10,888 cubic yards less than the Company's engineer certified to—a difference of less than 3 per cent. Their classification being somewhat higher than that of the Company's engineers, rather more than made up in value the shortage in quantities.

March 23, 1891, the sub-contractors filed a lien, entirely ignoring the quantities and classification of their engineers, Mitchell and Thomes. They used, approximately, the quantities of the final estimates given by the Company's engineers, but they slightly increased them in places. The classification claimed in the lien, although not entirely different from that of the Company's engineers, was, however, founded apparently on no actual measurement, but was made up by arbitrarily transferring large

quantities from earth to loose and solid rock, just as whoever made it up deemed advisable.

Apparently to support these small changes of quantities and large changes of classification, the sub-contractors had their work again measured and classified in September, 1891, by an engineer with three assistants. The pay yards he returned were 42,370 in excess of the final estimates of the Company's engineers—nearly 12 per cent. greater. The lien was assigned to an outside party and suit brought in the United States Circuit Court, District of South Dakota.

At sub-contract prices the value of the work done, by final estimate, amounted to	$87,380 34
The lien claimed a value of	118,350 96
Sub-contractors' engineer claimed a value of	128,184 32
Showing an extreme difference in value of	40,803 98
In addition, the lien claimed for delayed right of way, and consequent work after frost	29,936 22
For changes of section bounds, line and grade	14,658 40
For miscellaneous extra work	4,164 00
Making the gross difference of values	$89,562 60

From the amount directly involved, and the value attached to this case as a precedent, it has attracted much attention. "The taking of the evidence alone required two months' time, and when transcribed, filled 4,000 typewritten pages, besides which there were between 300 and 400 exhibits introduced and made part of the testimony. All of this vast volume of evidence was finally referred to Judge Bennett by order of Judge Edgerton. The hearing before Judge Bennett was most extensive, the arguments alone taking thirteen and a-half days' time. Messrs. Martin & Mason, Schrader & Lewis, and Mr. C. M. Brown appeared for plaintiffs, Messrs. Marquett and Griggs for the Railroad Company, and Mr. Frawley for the chief contractor. After Judge Bennett had carefully considered the case and had gone over the work in question, personally, in order to satisfy himself as to what the facts really were, he made an exhaustive report, sustaining fully the estimates of the Company's engineers, finding upon all points at issue in favor of the defendants. To this report the plaintiffs filed numerous exceptions, which were argued before Judge Dundy by Mr. Martin and Messrs. Griggs and Frawley. In addition to the oral arguments, briefs were filed by the attorneys and the case most carefully presented to the Court. Judge Dundy rendered a decision upon these exceptions in which he fully sustained the determination of Judge Bennett.

"There were many nice and intricate legal questions involved in this suit, turning upon engineering practices, all of which were

decided in favor of the methods and determinations of the 'Burlington' engineers."

From this brief history of a suit, that it has taken four years to determine, we turn to those parts of the decision that are of special interest to civil engineers.

QUANTITIES AND CLASSIFICATION.

The pay yards of earthwork were returned as follows:

	Earth.	*L. Rock.*	*S. Rock.*	*Totals.*
By Company's engineers . . .	223,954	77,987	51,393	363,334
By lien	116,211	188,483	63,395	368,089
By sub-contractors' engineer .	127,822	212,330	65,552	405,704

A careful inspection of these figures shows a more extraordinary difference in classification than the 42,370 cubic yards difference in total pay yards. Judge Bennett, the Master in Chancery, says in his report to the Court: "The measurement and classification by the sub-contractors' engineer are not entitled to any weight in the consideration of this cause for the following reasons:

"(1) In the measurement of cuts he included practically all the quantities found by him to have been removed, notwithstanding that (1) the contracts required that the quantities to be paid for should be ascertained from the cross-section notes of excavation and embankment prisms, and that only such quantities should be computed as were found within the slope, grade and surface planes; (2) by this method he disregarded the provision of the contracts by including large quantities of material not within the slope, grade and surface planes, thus greatly increasing the quantities above what they should have been; and (3) his measurements included, as having been done by the sub-contractors, a large quantity of material which had not been removed by them, but had been taken out by the Railroad Company after the sub-contractors left the work.

"(2) He determined the quantity of borrow by measuring the pits from which it had been taken, wholly disregarding the provision of the contracts requiring that all borrow should be measured in embankment, and greatly increasing the quantity over what it should have been.

"(3) In his classification he was not governed by the contracts under which the work was done. On the contrary he classified material which had been removed from the channels by plowing with six horses or mules, or less, as loose rock, for the alleged reason that channel excavation was more difficult to handle than like material found elsewhere.

"Again, he was governed in classifying alone by geological consid-

erations; or, in other words, by the appearance of the material adjoining that which had been removed, and wholly ignored the provision of the contract requiring that material should be classified according as it could be removed—for instance, that earth should include all material which could be plowed with a good plow, drawn by six good horses or mules, etc., and should include everything not distinctly loose or solid rock."

Another reason for large differences in quantities was that the engineers of the Railroad Company substantially gave the true prismoidal quantities, while the quantities given by the sub-contractors' engineer were obtained by averaging end areas without correcting in any way for the most extreme differences in consecutive cross-sections, although he took his cross-sections much further apart, usually, than the Company's engineers did, thereby much increasing the need of correction. He carried the method of averaging end areas to the extreme of using it at both ends of every cut on side-hill; that is, he invariably treated material which was actually pyramidal in form as being wedged-shape, thereby increasing the quantity by fifty per cent. An attempt was made in the evidence to show that custom had established the method of averaging end areas without correction; in effect, legalizing it. To disprove this the defendants introduced in evidence the following portions of standard works:

Computation from Diagrams of Railway Earthwork, Wellington. Preface, page 4.

"Economic Theory of Location of Railways, Wellington." Page 896, articles 1257 and 1258.

"Field Engineering," Searles. Page 203, article 235; page 225, article 254; page 229, article 256; page 236, article 263; page 200, article 231; page 201, article 232.

"Excavations and Embankments," Trautwine.

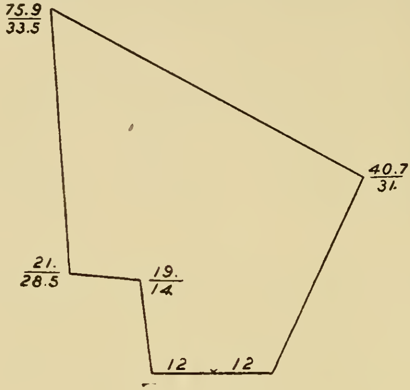
"Engineer's Pocket-Book;" twenty-fifth thousand; p. 161, Trautwine.

"Mensuration of Volumes." Page 129, Davies' Legendre.

They also claimed a strict interpretation of the contract, which says: "Payment being made only for number of yards actually removed by contractor, within the specified slope, grade and surface planes," and "Earthwork will be computed from cross-section notes of excavation prisms; that is, the quantities between the slope, grade and surface planes shall be taken, and shall be paid for by the cubic yard of twenty-seven (27) cubic feet."

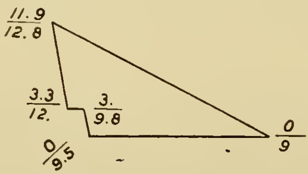
To show the importance of this question of methods, and the extortion that an unscrupulous engineer might perpetrate by a judicious misuse of the averaging end area method without correction, several test cases were selected from the cross-sections as measured and used by the

sub-contractors' engineer, models were made and put in evidence, and the differences between the two methods of computation amply testified to. In one instance that engineer added, according to his own measurements, in a prismoid only 32 feet long, 439 cubic yards of excess, and this in solid rock. Below is his cross-section at station, 2168+64.



STATION 2168+64.

His next note is "Grade at 2168+96," and he estimated the excavation between these two cross-sections, 32 feet apart, by simply averaging end areas. If any reader doubts the absurdity of using the average end area method without correction, in figuring quantities between such highly different cross-sections, he is advised to figure correctly and compare results. As this work was on steep side-hill the solid between these two plusses was not a true prismoid, and to figure the true quantity from the above notes it was necessary to interpolate a section at the grade point on the right, 2168+91. Below is the resulting cross-section at that plus.



STATION 2168+91.

The sub-contractors' engineer estimated between

2168+64 and 2168+96	1,672.4	cubic yards.
Correct prismoidal quantity	1,233.7	"
Error of method in 32 feet length	438.7	"

This is an extreme case, and simply emphasizes the necessity of correcting, in such cases, the results obtained by averaging end areas. In

this connection it is proper to call attention to, and heartily endorse, Mr. Wellington's Article 1258 of his "Economic Theory of Location of Railways": "The proper method of computing earthwork in construction is to compute by end areas only, and then at any later time, when convenience serves, to determine the prismoidal correction for those solids only which need it, which are those differing by more than two or three feet in center-height. These corrections are then added together for each cut or section and deducted in gross from the end area volume. The reasons which make this method at once the simplest and the most accurate of all, and the evidence from experience that it is so, are given at length in the writer's treatise on the computation of earthwork."

A further reason for the excessive pay yards estimated by the contractors' engineers is their complete ignorance of the natural surface of cuts, channels and borrow pits, necessarily removed in construction before they went upon the ground; in one place they counting the surface fully 25 feet above what it had actually been. By the contract they should have found the amount of the borrow by measuring the banks and deducting from their amount the total available material from cuts, channels, etc.; instead of so doing they attempted to measure the borrow pits, assuming the surface to have been straight from side to side in spite of the fact that many of the pits were over 100 feet wide and were in the edge of the valley, where the hill joined the bottom, and were thus almost necessarily concave on top, containing very much less than the quantity computed. The evidence was conclusive that in certain places the banks contain thousands of yards less than the contractors' engineers found in the cuts and borrow pits. So much for ignorance of the natural surface.

Classification, under the contract, depended upon how it was practical to work the materials encountered; and was a matter of demonstration to the engineers who were upon the work throughout construction; but to those going upon the work after completing it was, necessarily, merely a matter of opinion; proof could then go no further than to attempt to classify what had been moved by inference from what had not been moved.

Portions of the line for which it was necessary to borrow were in narrow valleys where earth was rather scarce, but the contract required the contractors to borrow earth at the price of earth excavation, if to be found within the limit of haul—which was 1,500 feet. Free haul was 500 feet. In a few places loose rock, and even solid rock, was borrowed in spite of the protests of the engineers, and although earth was in every instance pointed out, and the attention of the sub-contractors and the foreman was called to the provision of the contract; the sub-contractors and foreman explaining that they were short of teams to haul the earth,

and that it was cheaper for them to put the loose rock in with wheelbarrows and men on account of the much shorter haul. Counsel for plaintiffs claimed that the engineers should have peremptorily demanded the hauling of earth—if it were there—and, if their orders were not obeyed, should have enforced their demands by requiring the discharge of all foremen not acceding to them. Counsel also claimed that since rock was thus taken it must be paid for, and that, since the Company's engineers had made no measurement or classification of borrow pits, and the sub-contractors' engineers' had, the classification of the latter was the only classification before the Court, and must be taken. This claim, like all others, was set aside.

The sub-contractors' engineers measurements exceeded those of the Company's engineers about as follows: In cuts, 24,533 cubic yards; in channels, 3,500 cubic yards; in borrow, 14,337 cubic yards. The excess in cuts came from the causes already named and from numerous errors, which, by a strange fatality, seemed to always be on the sub-contractors' side. Ignorance of the natural surface was a large factor here, as in borrow; cuts were figured over a hundred feet longer than they really were, many were figured wider; nearly all material removed up to September, 1891, was estimated, although fully 20,000 cubic yards had been removed by the railroad employees after the sub-contractors left the work.

The difference of 3,500 cubic yards in channels is fully accounted for by (1) including, in at least two places, natural channel which never was excavated by sub-contractors; (2) ignorance of natural surface; (3) the natural wash of seven months, including spring freshets.

The difference of 14,337 cubic yards in borrow came slightly from error and from methods of figuring, and from waste in hauling and shrinkage (which, by the contracts, were chargeable to the sub-contractor), but principally from ignorance of the natural surface before alluded to.

At sub-contractors' prices the total values of earthwork were:

By Company's engineers' final estimate quantities	$ 82,536 49
By lien quantities	110,534 86
By contractors' engineers' estimate quantities	120,368 22
Showing a range in values of	37,831 73

The Master and the Court decided, however, the Railroad Company's engineers' estimate to be in accordance with the contracts and the evidence.

MINOR CLAIMS UNDER THE CONTRACT.

In PAY HAUL the engineers develop no difference of estimate.

In RIPRAP the Company's engineers' estimate was for 592.6 cubic

yards at $1.25, and the lien claimed 1,299 cubic yards at $2.00. As to the price, all the other riprap on the line was sub-let at $1.25, but through an oversight the item was not named in this particular sub-contract. The difference in quantity arose from over estimate of thickness, some of it (from coarseness of material) having been built thicker than ordered, and from including as riprap mere rock slope, which the Company's engineers claimed the right to have built, within haul of clear rock cuts, by simply dumping the coarsest of the rock in cart-loads, as it came from the cut, on the side of the bank toward the stream, under a clause in the specification: "Where there is choice of material, the best shall be used on top of the embankment, for at least one foot in depth, *or as directed* by the engineer." In the award there is a slight error in figuring, but the Master seems to have adopted the measurement of the Company engineers, but to have made his sole concession to the claims of the plaintiffs by figuring the price at $1.75 per cubic yard.

In CLEARING, the lien claimed 97.6 acres against 82.8 acres allowed. This relatively small difference arose from the difference in interpretation of the only clauses in the contract relating to clearing:—"Clearing will be paid for by the acre for ground necessarily cleared for grade and borrow pits;" and one other, which is a mere naming of price:—"Clearing, per acre" (when necessarily done). The Company's engineers held, where clearing was scattering and only a small portion of the ground was shaded, that, except for the portion actually cleared, clearing was not done, therefore could not have been *necessarily* done, and therefore was not to be paid for. Plaintiffs claimed that where any clearing was called for, it should have been estimated as solid. The Court adopted the interpretation of the Company's engineers.

In GRUBBING, the same difference in interpretation developed as in clearing. The only clauses relating to grubbing in the contract were:—"Grubbing will be paid for by the station where necessarily done. Grubbing sage-brush and grease wood will not be paid for, but the price paid per yard for grading shall include the cost of such work;" and, "Grubbing, per station" (where necessarily done). The engineers measured all grubbing along the line and along detached work (like channels, etc.), figuring, in fractions, the next larger tenth of a station. The lien claimed even a single stump as a whole station. Then, of course, an estimate of grubbing, after the completion of work, is, necessarily, a mere guess from the appearance of the surroundings. The difference in value of all those minor claims under the contract was $2,972.25, only.

EXTRA WORK.

The lien claimed for *delayed right of way*, etc., and consequent work in *frost*, an additional price of:

12	cents per	cubic	yard	on	16,351	cubic yards earth		$1,962 12
30	"	"	"	"	47,122	"	earth and loose rock.	14,136 60
50	"	"	"	"	11,046	"	(partly solid) . . .	5,523 00
100	"	"	"	"	6,282	"	. . . .	6,282 00
125	"	"	"	"	1,626	"	. . . .	2,032 50
				"	82,427	"		$29,936 22

Included in this total is a claim for, perhaps, $5,000 for change of line, which neither the lien nor the evidence makes it possible to separate from the delayed right-of-way claims, but which is barred out by this clause in the contract: "The party of the first part reserves the right to change the line and grade from that shown on plans and profiles furnished, but will not be held for damages on account of such changes."

This line ran through a strictly mineral country; claims lay around loose in all directions, overlapping each other—some of them abandoned. It was impossible for an outsider to be sure of the legality of any title till it had fought its way through the courts. Often no sign of occupation showed until, after construction had begun, the owner (?) appeared with shot-gun or revolver, and a violent temper. Right-of-way agents were kept traveling back and forth in the endeavor to keep all claims settled as fast as they could be believed genuine. Occasional threats were made, and, in a few places, gangs of men were forbidden to work, but only one injunction was served, and no actual force was used to prevent work. The evidence shows that the injunction was in force only about four weeks.

The whole matter of delayed right of way and work in frost was thus summed up by the Master in Chancery (eliminating legal terms and repetitions): "The claim for extra compensation, on account of alleged *delay* caused by the alleged failure on part of the railroad company to obtain right of way, by reason of which complainants claim that a large amount of work had to be done after frost had set in, is not sustained by the evidence; the sub-contractors not having been delayed in their work by reason of any act or default on the part of the defendants, or either of them. On the contrary, the sub-contractors kept all of their forces employed, and were not compelled to turn off either workmen or teams on account of the want of such right of way. The sub-contractors were not prevented by injunctions or default of defendants from completing their work within the time stipulated in their contract. Moreover, they never made any claim for damages, or demand for extra compensation to the defendants herein, or either of them, in any manner whatever. Again, the sub-contractors, if delayed by want of right of way, were allowed a much longer time by the railroad company than the period of such delay, in which to complete their work, after the date when it should have been finished.

"The claim for extra compensation or allowance, on account of work alleged to have been done at Nahant, after frost had set in, is not sustained by the evidence, as said grounds were staked out by the Company's engineers in ample time for all of the work to have been done before frost set in.

"The claim for extra compensation or allowance, on account of certain berms and channels, alleged by complainants, to have been staked out by the Company's engineers, after frost set in, and which, therefore, had to be graded in frozen material, is not sustained by the evidence, the berms and channels having been staked out as soon as required by the sub-contractors, and some of them long prior to the setting in of frost."

The lien claimed for changes of section bounds, line and grade, these items:

30 cents per cubic yard for 32,307 cubic yards on account of changing trestle work to fill across gulch, and moving line between sections 77 and 78 from station 1829 to station 1830, increasing fill from 3,340 cubic yards to 35,647 cubic yards	$9,692 10
10 cents per cubic yard additional for 23,422 cubic yards on account of difference between placing in spoil bank and hauling into line bank	2,342 20
Increased cost of work made necessary by change of line from station 2170 to station 2182+50, 30 cents per cubic yard additional for 8,747 cubic yards; a portion of this was hauled past section end and a large portion was hauled past bridge opening at station 2188	2,624 10
Claimed for changes ordered by engineers	$14,658 40

Besides a claim, previously alluded to, for about $5,000 that cannot be separated from the claims for delayed right of way.

The claims for changes made by order of engineers were thus disposed of by the Master in Chancery: "The claim for extra compensation or allowance, on account of an alleged changing of the section ending, at the north end of section 77, is not sustained by the evidence for the reasons that the sub-contractors agreed in the written contract to do the work up to the point where the section was actually ended; and, even if the section ending was changed, the Company's engineers had the right to change it, and no injury was done the sub-contractors.

"The claim for extra compensation or allowance, above the award made by the company's engineers, on account of the change of the section ending between sections 83 and 84, is not sustained by the evidence, for the reasons that the contract, under which the sub-contractors did this work, permitted such change to be made by the Company's engineers, and such change of section ending, worked no injury to the sub-contractors."

In the lien were presented miscellaneous extra bills, which may be grouped thus:

1. Clearing out channel of creek opposite heavy rock cut	$956 00
2. Waiting for placing of culvert; 4 teams, fifteen days at $4	240 00
3. Widening cut slopes—partly on account errors of engineers	938 00
4. Putting rock filling in crib—730 cubic yards at $2.00	1,460 00
5. Removing old flume and slab pile	94 20
6. Rock in creek for road crossing	6 50
7. Building and removing bridges for hauling borrow, etc., ...	197 30
8. Clearing and grading roads	272 00
	$4,164 00

In his report to the Court the Master in Chancery thus disposes of these: "The engineer gave no orders in writing, or otherwise, to the sub-contractors requiring the latter to do any extra work for which they were not estimated and allowed in the final estimate."

Some particulars of this extra work may be of interest to engineers:

(1) Heavy blasting in rock cut threw large masses of rock into a creek channel, forcing the water from it over a public road. The contract provided that the contractors were to be held liable for all damage to premises through which the road ran, and that the Company might retain an amount sufficient to cover those damages.

(2) The evidence was conclusive that the culvert in question was in place nearly a month before the delay was alleged to have occurred.

(3) The evidence was positive that no errors in cut widths or slopes were made by engineers. During construction, slopes were flattened because less stable material was encountered than was expected. All excavations ordered, and all slides that seemed unavoidable because of natural seams, were paid for.

(4) To fill a crib (built by other parties) the sub-contractors were told to get rock wherever most convenient, and they were paid for the estimated amount of solid rock excavation that was required to fill the crib, since it seemed to the resident engineer that he could, under the contract, have staked out an excavation in solid rock and required the material dumped into the crib, and no good reason appeared for paying a greater price for the easier service required.

(5) Removal of saw-mill débris and an old flume were held sufficiently paid for by clearing—especially as much of the material was converted by the sub-contractors to their own use for wheel-planks and to build sheds.

(6) Rock in road crossing was merely loose rock borrow.

(7) Building and removing bridges that were for the contractors' convenience: it is doubtful if these should have been paid for by the Company. These were not paid for as extra bills, but were liberally

equated in value as "clearing." This practice of equating the value of something not covered by the contract in terms of some item in the contract seems very objectionable to most engineers, but was not disturbed by the Court.

(8) Clearing and grading roads were clearly covered by items in the contract, and were properly covered by the estimate.

The petition sets forth the cause of action thus: "That when the work was completed the Chief Engineer made a pretended final estimate showing the quantity and classification of the work done by the sub-contractors under the contract, which pretended estimate is wholly false, fraudulent and erroneous; and, although the sub-contractors actually performed the amounts of work and at the prices specified in the annexed claim and lien alleged, the Chief Engineer, by fraud, error and mistake in his final estimate, estimated the work done by the sub-contractors as follows:" (Setting forth, with a few clerical errors, the correct amount as stated in the final estimate by the engineer.) As to these charges the Master reported to the Court: "The engineers of the railroad company acted fairly and in good faith in all matters pertaining to the measuring, classification and estimating of the work done by the sub-contractors, and the measurements, classification and final award were justly and fairly made according to the best skill and ability of the engineers."

The Master also reported to the Court these conclusions: "A legal and valid estimate and award of all work and labor done and material furnished by the sub-contractors, under the contract, was duly made and rendered by the Chief Engineer of the Railroad Company, as required by the contracts hereinbefore mentioned, and said estimate and award was and is binding upon the sub-contractors and the complainants herein.

"The complainants are entitled to take nothing by this suit, and the defendants and each of them should go hence without day."

EFFECT OF THE DECISION.

For several years the practice has existed to an undesirable extent among engineers, especially in the West, of classifying work according to its cost—using some judgment, of course, with regard to its management. Plainly stated, the theory seems to have been that, if a piece of work was well managed, the final estimate should show a profit, and that if badly managed it should show a loss. The price and other items of the contract have played second fiddle in the harmony (?) of construction. This practice has even been urged in papers presented by engineers of reputation to engineering societies, and has resulted in debauching the contractors and engineers; has put a premium on low and hishonest bidding by encouraging the idea that the main thing was

to bid low enough to get the work anyhow—depending then upon the mercy and dishonesty of the engineers to make the profits all right; has put a premium on poor management by contractors, since the tendency was for the engineers to rely upon the force account to determine the classification, and thus pay a poor manager more for doing a given amount of work than a good manager for doing the same: and, by preventing their getting the work, has injured the honest contractors—who made fair bids, expecting measurement and classification according to the contract and specifications—more than it has injured any others.

Against this improper practice, and in favor of a strict construction of contracts and specifications, this fight has been sustained for five years. To make the position tenable the policy was carefully inculcated of making no presents, but of giving to the contractors the benefit of every reasonable doubt.

The engineers on this work were: I. S. P. Weeks, Chief; F. C. Tucker, Resident, and F. A. Jones, F. C. Noble and J. C. Beye, Division. As an expert on methods and classification V. G. Bogue was called, after suit was begun, and his vigorous endorsement did signal service.

In closing, apology is due the attorneys in the case for the freedom with which the "saids" and "aforesaids" have been dropped in quoting from the carefully prepared law papers.

Editors reprinting articles from this journal are requested to credit both the JOURNAL and the Society before which such articles were read.

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APPROXIMATE ANALYSIS OF THE USE OF COAL IN AN EDISON ELECTRIC STATION OF THE TYPE STANDARD, ABOUT 1890.

BY R. S. HALE, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society, May 15, 1895.*]

THE system of electric supply from which the following results are derived is the Standard Edison system of a 3-wire underground network for low tension, direct current supplied by underground feeders from three stations, located in Boston, one on Head Place near the corner of Boylston and Tremont Streets, one on Hawkins Street near Bowdoin Square, and one on Atlantic Avenue, foot of Pearl Street.

These stations pump electricity into the electric mains exactly as pumping stations or gas works might supply water or gas, only since the incandescent lamps must be supplied at almost absolutely constant pressure an electric network requires more feeding points than a network of water mains, or gas mains.

The stations are as follows: The first station on Head Place has 18 units, each consisting of an Armington & Sims non-condensing engine, 15 x 15½ inches, belted directly to two Edison No. 20 B. P. dynamo. Each dynamo is rated at 400 amperes and 125 volts or 50 K. W., the engines at 135 H. P. The engines are supplied with steam at 95 pounds pressure from six return tubular boilers of 1,800 square feet of heating surface each, and five Babcock & Wilcox boilers of 3,220 square feet of

* Manuscript received August 7, 1895.—*Secretary, Ass'n of Eng. Socs.*

heating surface each. The second station on Hawkins Street has ten exactly similar units supplied with steam at 100 pounds pressure from two Heine boilers of 2,600 square feet heating surface, one Heine of 1,640 and two Babcock & Wilcox boilers of 2,795 square feet heating surface each. At the Atlantic Avenue or third station are four triple expansion marine type condensing engines of 650 H. P. each, direct connected to two 200 K. W. General Electric, M. P. dynamos. These engines are supplied with steam at 160 pounds from seven Babcock & Wilcox boilers of 3,737 square feet each. There is also a storage battery of 140 Tudor cells of 3,470 ampere hours capacity on each side of the 3-wire system.

The supply of electric current, which may be used for incandescent lamps, arc lamps and motors indifferently, and is supplied at 110 volts, or 220 volts between the outside wires of the 3-wire system, is best shown by our load curves. Here is a curve, Fig. 1, of a summer day beginning 7 A.M. The first part of the curve is the motor load and office lighting which drops off for lunch at noon and again at 5 P.M. The evening load is residence and shop lighting. In the spring and fall, represented by the curve in Fig. 2, day and night load merge into each other, and in the winter, Fig. 3, they overlap, giving us this peak.

The dotted curves below the full curve of total output are the curves of the districts normally supplied by the different stations. Now the third station is of higher first cost and also of much less operating cost than the other stations. You can readily see that it would not pay to pay interest on costly apparatus to supply this peak that lasts only a few hours a day a few months in the year, independently of the copper needed to transmit this maximum load to the other parts of the city, but yet at light loads it seemed a pity to have costly engines lying idle while cheap ones were eating up the coal pile. Large feeders or tie lines were therefore put in with the idea of carrying our average load during the great part of the time on the engines of good economy, using the Head Place and Hawkins Street stations only as reserve and to supply the peak of the winter curve. The result is that with less than 40 per cent. of our investment in high-priced economical machinery, we are able to carry over 90 per cent. of our average load on it. It is the same principle as putting in a good pumping engine for water service and a cheap one for reserve and for fire service, only it is a little harder to work out for electric supply.

Up to May, '93, we had no tie lines and ran the engines at each station to supply the normal load of the district. Since May, '93, we have been able to shut down the uneconomical stations a large portion of the time, bringing down their average load and bringing up that of the third station. The effect of the tie lines is shown by these curves, Fig. 4, which

give the load manufactured by the different stations and the total. The first three figures give the curves of distributed load. Unfortunately only the second station is available for the comparisons of the use of coal we are now about to make, since the first station supplies a great deal of steam heat of which no record can be made, while various causes in addition to the change of load have affected the third station. For the second station we have the following data by months: Tons New River coal. Tons wharf screenings. Average K. W. Engine hours. These are obtained as follows: At the first of the month coal on hand is measured, amounting to from 50 to 100 tons. All coal brought into the station is weighed on the carts and at the end of the month coal is again measured. Coal weighed + or — difference on hand, is coal used, and

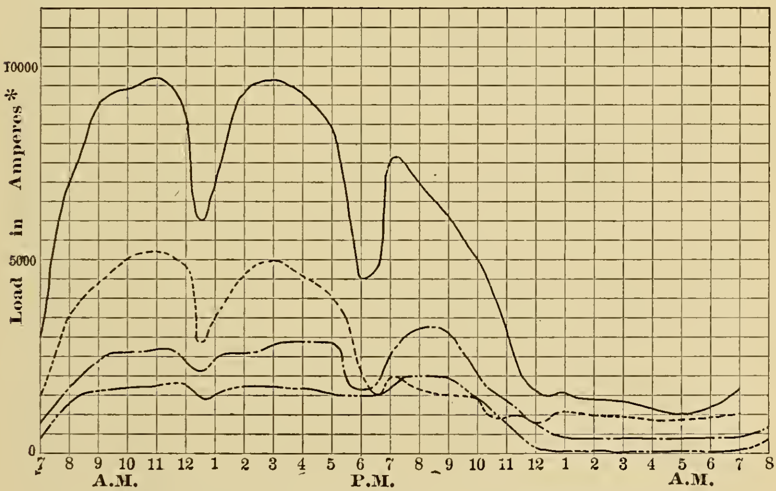


FIG. 1.—LOAD DIAGRAM, AUGUST 21. WEATHER FAIR.

is divided between New River and screenings in proper proportion. Half-hourly records are kept of the amperes and volts, which give the K. W. hours, and hourly record is kept of the number of engines running. We then get the derived figures of pounds coal per hour and per K. W. hour and average K. W. per engine. (See table.) These *figures* only show a much worse economy at small average loads, but drawing with average K. W. as abscissæ, two curves, Fig. 5, of pounds coal per hour and pounds coal per K. W. hour we find fairly regular curves, showing that there is a law connecting them. Examining the right hand side of the first curve we find a straight line whose equation is

$Y = a + b\,x$. Where $Y =$ pounds coal burnt per hour $x =$ aver-

* At a pressure of 110 volts at feeder ends.

age K. W. a and b constants which work out to $a = 500$ pounds, $b = 7\frac{1}{2}$ pounds.

These are obtained using only the right hand portion of the straight line curve, which represents times when the station was ready to turn out its full load or nearly so. The left hand portion is when some of the boilers and some of the steam piping is shut down, making in fact a smaller station, which accounts for the droop. In our equation we will first put the load, or x = 0. Then y = 500 pounds per hour, which is what is necessary to keep the station ready for full load without turning out any load. The other constant is evidently the pounds per

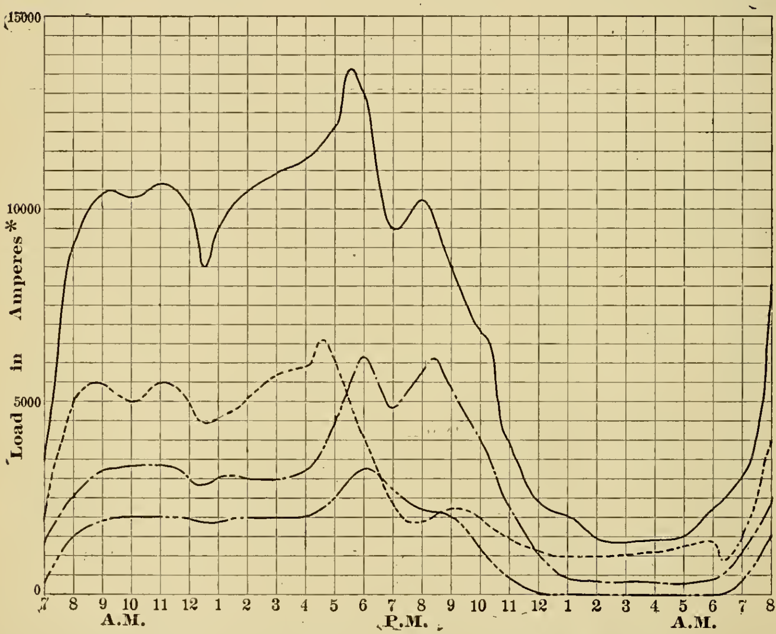


FIG. 2.—LOAD DIAGRAM, OCTOBER 1. WEATHER CLOUDY.

K. W. hour of any additional load after paying the 500 pounds per hour to keep the station ready. Seven and a half pounds of this coal per K. W. hour is equivalent to about 50 pounds steam per E. H. P., or near to 40 pounds per 1 H. P. hour, and since the engines are necessarily run a large part of the time either under- or overloaded, this does not compare unfavorably with the figures obtained for this class of engines on test runs.

It should be noted that there are enough engines so that the over- and under-loading of the engines is not markedly different for different

* At a pressure of 110 volts at feeder ends.

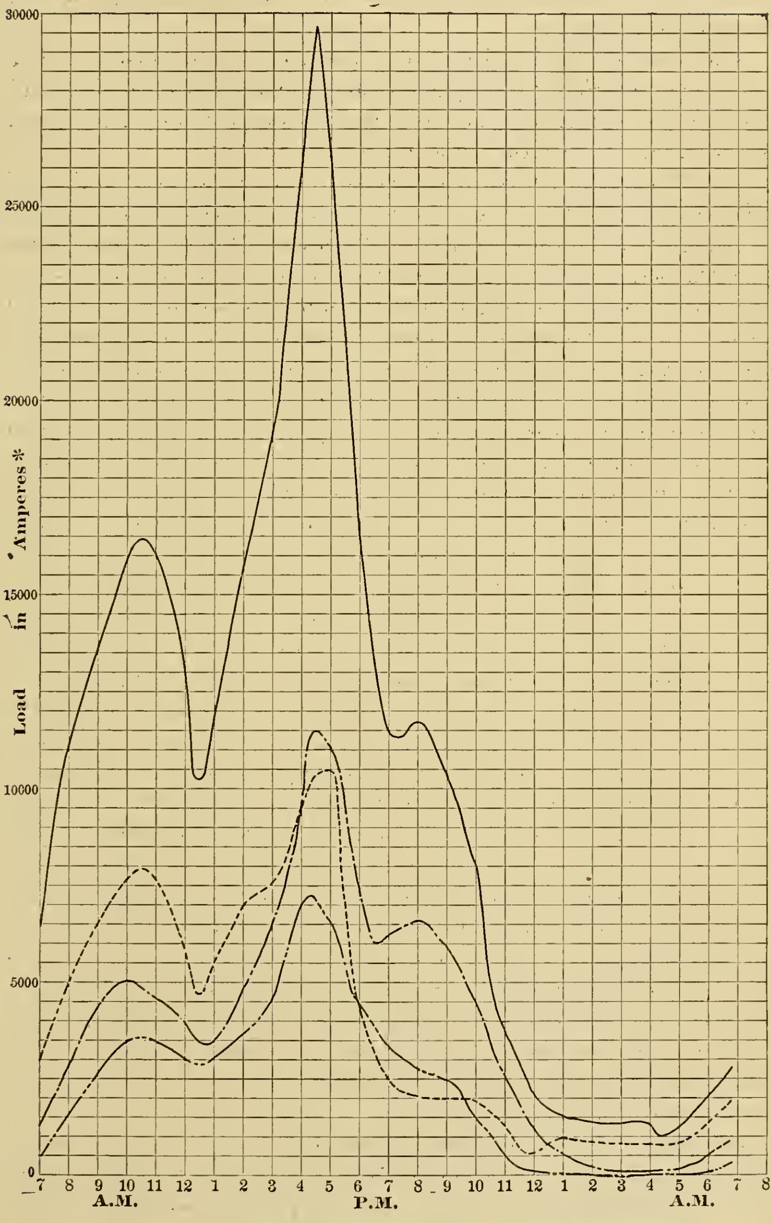


FIG. 3.—LOAD DIAGRAM, DECEMBER 12. WEATHER CLOUDY.

* At a pressure of 110 volts at feeder ends.

average loads on the station as is shown in column of average K. W. per engine in the table.

This constant loss of 500 pounds per hour is composed of boiler losses, which are hot chimney gases, and radiation from boilers, and steam pipe losses, including radiation from steam pipes and steam leaks. The two latter were determined as follows:—

All drips were returned by a Gassett trap to a large tank half filled with cold water. The size of the tank being known the increase in depth gave a measure of the condensation. All the engines were shut down, hence the total water used as per meter during the test or seven hours corrected for height of water in boilers and minus the water condensed, was a measure of the steam or water leaks. The result was surprising, the leaks amounting to about 500 to 600 pounds water of steam per hour, the condensation to only about half that amount on a warm winter night. Another test on a very cold night gave about 800 pounds leak per hour, a condensation in only a part of the piping was about 400 pounds. Still another test, with one half of the steam piping and all but two boilers shut down, gave radiation 200, leak 600, on a moderately cold night. A test one moderately warm day gave 500 pounds leak per hour. The condensation includes the heating of the second story of the building. The daily figures for water consumption at light loads after allowing an estimate for use for water closets, etc., and for actual steam in engines themselves, bear out these figures. As these figures for leak seem very large, I wish to say that at our third station the tests show still larger loss than at the station under discussion, yet at least one member of this society has twice complimented me on the excellent job of steam piping there. Besides, 600 pounds per hour for even 20 hours is only about 200 cubic feet, and when boilers are left low at end of run and then pumped full to be ready for the next run, such a quantity may easily pass unnoticed. The contraction of water when cooling and the curious vagaries of the water in the water glass of a banked boiler would also help the leak to escape detection, without special tests.* Six hundred pounds steam leak is about 66 pounds coal per hour. Say 300 pounds steam condensation is about 33 pounds coal per hour. Subtracting these from the total of 500 pounds, leave as the boiler losses about 400 pounds coal per hour for say for 4½ boilers on an average.

Separate tests indicate that it takes about ¾ ton coal per day to keep up the pressure in a boiler of 250 to 300 H. P., without making any steam, which, allowing for somewhat greater loss at full load, checks up the figure of 400 pounds we have just obtained as well as we can expect in any discussion of this sort.

* See also *London Engineering*, April 5, 1895, for the amount of this loss in steamship practice.

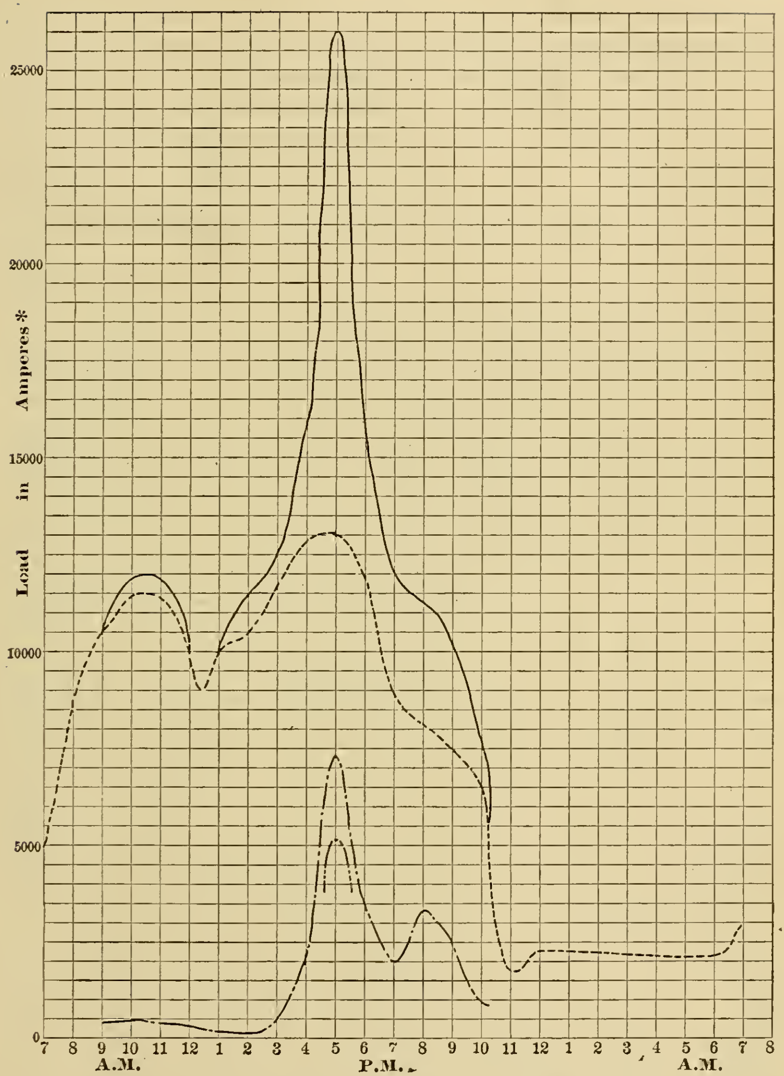


FIG. 4.—LOAD DIAGRAM, DECEMBER 13. WEATHER FAIR.

It seems probable that the boiler losses may be chiefly in the chimney and not in direct radiation when we remember how long a boiler will keep up its pressure with the fire drawn, provided the damper is tightly closed, but some boiler trials I have made render me very chary of forming a definite opinion on this subject. We then have for this

* At a pressure of 110 volts at feeder ends.

station of 1000 K. W. capacity, 1350 rated I. H. P., 12,390 square feet boiler heating surface.

66 pounds coal per hour . . steam leaks.
33 " " " " . . radiation from steam pipes.
400 " " " " . . hot gases and radiation from boilers.

Total 500 " " " " . . constant loss independent of load.

Power produced 7½ pounds per K. W. hour in addition to constant loss.

It need hardly be said that these figures should not be considered as an exact analysis, but merely as giving an idea of the relative value of the quantities. Nor are they presented on account of their excellence, though there are many reasons in the nature of our business why we cannot ever get as good results as with the absolutely constant load of a pump, or nearly so of a mill, but I hope they will be of interest as showing some results of actual running. I may add that we are to-day producing power at our new station at a cost per unit less than half of what it formerly cost us in our present sub-stations.

	Tons N. R. Coal	Tons Dust	Eng. Hours	Ave. K. W.	Lbs. Coal per hour	Lbs. Coal K. W. hour	Ave. K. W. per Eng.
1893.							
January	421	333	2432	211.7	2032	9.57	64.7
February	386	292	2102	198.2	2080	10.16	63·5
March	417	338	2423	204.7	2036	9.92	62.8
April	256	256	1633	124.9	1424	11.4	61.2
May	147	163	612	46.8	836	17.8	56.8
June	79	99	114	7.8	496	61.5	50.8
July	54	54	7	.3	292		50.4
August	42	58	30	1.2	270		30.9
September	67	83	98	7.2	418	58.0	52.2
October	92	116	352	17.7	562	31.7	52.9
November	87	97	375	25.2	512	21.3	48.4
December	118	134	384	22.5	680	29.9	43.9
1894.							
January	104	105	596	37.9	748	19.6	47.4
February	98	111	415	30.9	622	20.2	50.0
March	92	109	299	20.9	542	25.9	52.1
April	60	69	184	14.4	258	25.0	56.4
May	7	9	0	0			
September	6	3	0	0			
October	29	29	87	7.0	156	22.3	52.9
November	86	91	256	21.8	492	22.7	61.4
December	150	155	412	41.1	822	20.0	74.1

By the kindness of the President of one of the Edison Illuminating Companies I am enabled to add as an appendix the following extracts from one of his reports. His station is very similar to the one we have been discussing, except that it is two or three times the size, and has some compound engines:

"Calling your attention to the fact that the operation of this station

is for the purpose of earning money, I would particularly call the attention of the Board to the excess of the relative consumption of coal on Sundays over week-days, as compared with the load. You are all aware that on Sundays the amount of coal burned per H. P. hour sold usually more than doubles the amount of coal burned on week-days; and for this reason our Sunday load is very unprofitable. This discrepancy, however, points out to us the existence of a very large constant waste, and by means of the proper comparison it enables us to determine the amount of this waste:

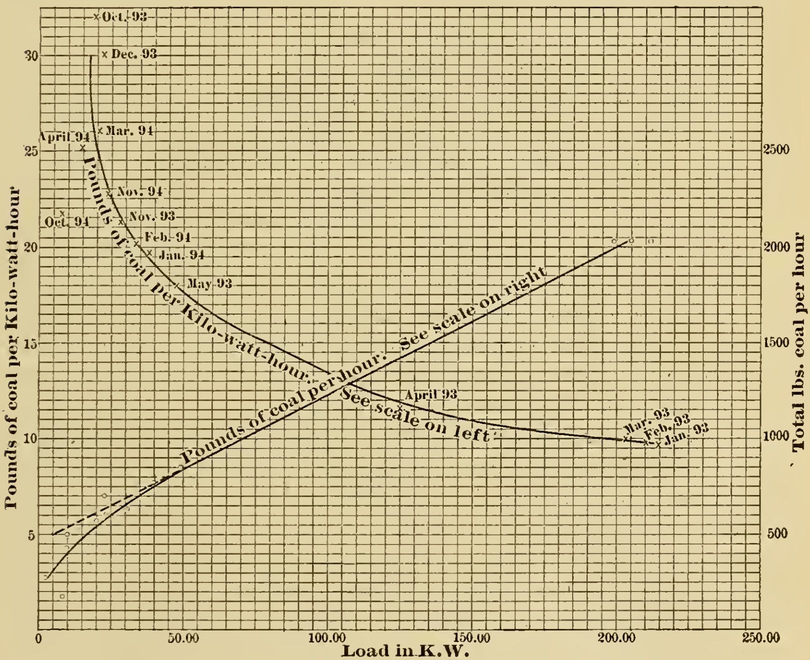


FIG. 5.—CONSUMPTION OF COAL AT SECOND STATION.

Average number pounds of coal burned	Sundays,	December,	1893	70,400
" " " " " "	"	April,	1894	62,000
" " " " " "	Week-days,	December,	1893	155,615
" " " " " "	"	April,	1894	106,680
Average Amperes,	Sundays,	December,	1893	1,450 2
" "	"	April,	1894	1,313.6
" "	Week-days,	December,	1894	5,512.0
" "	"	April,	1894	3,990.6
Average Voltage,	Sundays,	December,	1893	116.6
" "	"	April,	1894	116.3
" "	Week-days,	December,	1893	122.9
" "	"	April,	1893	120.0

SOLUTION.

Let W = waste per hour of coal or amount used in appurtenant machines, exclusive of the steam engines. R = true rate per K. W. hour.

For December, 1893, we have:

Sundays, per hour, $2933 - W = 1450.2 \times 116.6\, R$.

Week-days, " $6484 - W = 5512. \times 122.9\, R$.

$$(6484 - W)\, 169093. = (2933 - W)\, 677424.$$

$$W\,(677424. - 169093.) = (2933 \times 677424.) - (6484. \times 169093)$$

$W = 1791$ pounds per hour. 19 tons per day.

For April, 1894, we have:

Sundays, $2583 - W = 1313.6 \times 116.3\, R$.

Week-days, $4445 - W = 3990.6 \times 120.\ R$.

$$(4445 - W)\, 152771.7 = (2583 - W)\, 478872.$$

$$W\,(478872 - 152771.7) = (2583 \times 478872) - (4445 \times 152771.7)$$

$$W\,(326100.3) = 1236926376 - 679070206.5$$

$$W = \frac{557856169.5}{326100.3} = 17107. \text{ pounds per hour} = 18.3 \text{ tons per day.}$$

The data for the solution of the problem of the waste of this establishment has been gathered for me by Mr. A., as you see, and the numerical values in the equations for April, 1894, have been checked for me by Mr. B., in order to see if the numerical results for December, 1893, are approximately correct.

You will observe that this result of 18.3 tons loss per day very nearly checks the 19 tons loss per day as obtained by myself. The difference is probably due to the difference in temperature in two months.

In what I have to say, I will refer more particularly to December, 1893, which problem I have personally solved.

Subtracting 1,791 pounds loss from 2,933 pounds daily consumption for Sundays, I would say that the result shows 5 pounds of coal per electrical H. P. Also, taking up the question of week-days, substracting 1,791 pounds loss from 6,484 pounds daily consumption, the result shows 5.17 pounds of coal per electrical H. P. hour produced.

This is the coal used by engines and dynamos engaged in the conversion of steam power into electricity, and it is a very good result for non-condensing engines, such as we have with our very poor quality of coal.

DISCUSSION.

Mr. George H. Barrus.—Mr. Hale's interesting paper brings forcibly to notice two points of great practical and commercial value regarding the design and operation of steam plants for electric work.

The first of these is one pertaining to the provision of *cheap* engines, instead of *costly* ones, for relay power, and for use during the short periods of heavy load; and the other, to the great loss, due to leakages and careless handling, in steam plants which are engaged in the generation of electricity.

In a case like the Edison Company's plant, where the generating stations are divided up into a number of individual plants distinct from each other, where the feeder mains can be interconnected and the various plants operated as one complete whole, and where, as it happens, the machinery in one place is of the most economical type, while in another it is wasteful, the conditions lend themselves most readily to dividing the work, so that the constant load may be carried by the economical though costly engines, while the excessive heavy loads can be taken up and carried by the less economical engines. But the same principle can be profitably carried out, it seems to me, in any large individual station where the driving plant is made up of a number of engines. The design of such a station, embracing say half a dozen units, to be consistent throughout, would provide that the engines should be duplicates of each other. If it was thought best to employ high pressure and the most economical system of expansion, the same design would be carried out on each of the six units, so that whatever engine is brought into use it would work with the highest economy attainable. To be consistent in the design, I say, this is the plan which would be followed, although the high class engines would be much more expensive to install than a type which would consume more coal. But the days when consistency in design is the main thing to be considered are long past, and the important thing in steam and electric machinery nowadays is to get the most return for money invested, whether this be for non-condensing slide-valve engines which may use 50 pounds of steam per horse-power per hour, or from high pressure triple expansion jacketed condensing engines which may work on 11 pounds of steam per horse-power per hour. There may be some difference of opinion as to what class of engine is in the long run the most economical. Whatever this may be, it is easy to see that it is hardly worth while to install a costly engine for the sole purpose of a relay and for assistance to the main source of power during the short time when the heavy load is on, or during times of emergency, for during a large portion of the time the relay machinery is standing idle, or, at best, only partially loaded. It seems to me that these relay engines should be installed with a view to obtaining the largest amount of power with the least expenditure of money for the plant, and not with a view to economizing steam, for the question of fuel economy in this case is one of comparatively small importance.

The leakages and other losses due to improper handling in a steam

plant, composed of a number of units in accordance with electrical lighting practice, prove to be a serious matter, especially where the plant is carelessly handled. The multiplicity of parts, and the great number of valves and other complication in the connecting pipes which are required, makes it easy for such losses to go on, where in a more simple steam plant composed of only one engine they could be more easily detected and prevented. For this reason much greater watchfulness is required than in ordinary steam engineering work, and, consequently, in the absence of such watchfulness the trouble is greatly augmented. The extensive use of high pressure also contributes to increased leakages, for the reason that valves and fittings become disordered with high pressures much more quickly than otherwise, and when thus disordered the loss from leakage is much greater than with the same amount of disorder under a lower pressure. In the ordinary run of electric light stations I dare say that it would be a surprise to the engineer in charge if he were to know how much steam was wasted from his plant by leakage. In almost any case if he were to shut the throttle valves of his engines, making no other change than to stop the supply of steam to the cylinders, and, at the same time, keep one of the boilers in operation with a view to maintaining the regular pressure and keeping up a supply for whatever leaks there might be, he would find that a considerable quantity of coal would still be burned to make up this loss. The leakages through throttle valves, drip valves, separator traps, stop valves for connecting pipes, and through the many other branch pipes connected with the steam system which are provided for convenience in the operation of the station, some of which might be in a disordered condition, is, under the ordinary working practice, a large quantity. Mr. Hale's paper brings this fact out, and shows that even in a plant where every precaution is taken to obtain good service, as evidenced in the Edison Company's work, the same trouble exists, and it is of vital importance.

There is another point which concerns the economy of the boilers, and that is the loss due to banking fires. A fire may be banked and the boiler kept in condition for future work with very little loss of fuel, but this cannot be done unless the doors are closed and the damper is shut off so tightly that no cold air passes through from the furnace to the chimney. In the common practice this does not occur, for even with the damper nominally closed there is enough opening to produce a considerable current of cold air through the structure, and the result is that the boiler is cooled down, the inrush of air burns up the coal in the bank, and the loss thus sustained must be made good by the use of fresh coal, when the boiler again requires to be set to work.

SOLID FLOORS FOR RAILROAD BRIDGES.—THEIR MERITS AND THE CALCULATION OF THEIR STRESSES.

By Henry Goldmark, Member of the Western Society of Engineers.

The iron and steel bridges erected on American railroads, during the past few years, undoubtedly show a great improvement over the older designs. The changes consist in the use of simpler and better forms of construction, combined with a marked increase in the weights of the spans.

In fact, as far as the principal members are concerned, the cross-sections in our latest bridges are of ample size, and the unit strains are very moderate.

Few engineers will question the wisdom of thus providing a liberal amount of material to withstand the shocks and vibrations of rapidly moving trains. We must not forget, however, that the proper dimensioning of the truss members and the floor girders is after all only one part of a bridge design. The choice of the most advantageous form and depth for the trusses, the selection of a proper floor system, and, last but not least, the design of the details and connections are of even greater importance.

Undoubtedly, improvements have been made in all these points, but a candid observer can hardly doubt that there is need of much further progress. It has indeed been asserted, quite recently, and on excellent authority, that the evolution of the railroad bridge is practically completed, but history and the observation of present practice, alike refute any such theory of perfection.

It is, on the contrary, perfectly clear, that much work remains to be done in investigating the problems involved in bridge design and the best methods of solving them, before we can hope to succeed in building thoroughly rigid and durable as well as safe structures.

Railroad bridges may be divided into two classes, the requirements for which are widely different.

There are, on the *one hand*, large bridges, consisting generally of several spans of considerable length, and crossing important rivers. In such structures the dead weight of the iron work will necessarily be great, while the speed of the trains is likely to be moderate. The truss work of these long spans will be subjected to strains of essentially the same character as those produced by quiescent loads. Within reasonable limits the use of long panels and high trusses will not be objectionable on practical grounds, while it will, of course, produce a high degree of

economy. The advantages of pin connections, too, can be obtained without any accompanying drawbacks. Moreover, as the speed of the trains is slow, the floor system will not be subjected to excessive strains from impact, while derailments will rarely occur. In such bridges, economy of material is eminently desirable from every point in view, so long as the prescribed strength is maintained.

On the other hand, we have the great bulk of our railroad bridges, viz.: the shorter spans which form an integral part of our railroad lines. They are of moderate length, few of them being over 150 feet long, and are habitually passed over by trains at full speed.

The conditions to be met in designing such short spans are evidently very different from those to which bridges of the first class are subjected. Their length being small, the impact of the live load on all parts of the iron work is violent, and great care must be taken to minimize its effects. Mathematical analysis is of little service in settling the questions involved. The static forces contained in ordinary strain sheets are by no means a measure of the work the metal has to do, while the more complicated theories on secondary and impact strains are as yet scarcely in a shape fit for practical use. The engineer's judgment based on practical experience, and a study of bridges under the action of traffic, will have to be the main guide in designing.

Fortunately, iron railroad bridges have been in use long enough and in sufficient numbers to give an inductive method of this kind a good chance of application. Those bridges which have actually failed while in service, as well as others that have been replaced for structural weakness, present abundant material for criticism and study.

For short spans, more than for any others, the aim of the designer should be to produce a structure which shall act, as far as possible, as a single unit, with the least possible movement of the separate parts, as well as of the bridge as a whole. All types of truss, and all details and connections, which conflict with this requirement must be discarded. Economy should, of course, be studied, but it will be found to consist rather in using such forms as are simple in detail and easy of construction than in striving to reduce the weight of metal used to a minimum. As an increase in the weight of the iron work and the flooring is the most efficient means of absorbing shock and decreasing vibrations, any additional metal in a short span is of decided advantage, and the expense involved is usually small as compared with the total cost. In connection with this matter, it must be remembered that the actual expense of the shop work remains almost the same even though the weight of the sections be considerably increased. At the present time, steel shapes for bridge-work can be bought at the Pittsburg mills for a price barely exceeding one cent per pound, so that to adopt an economy of material,

which may shorten the life of the structure, appears more than ever a short-sighted policy.

A neglect of the above considerations was, however, quite general in American iron bridge-work at no remote period in the past. The sound practical judgment which had given to the world such valuable constructions as the Howe truss and the timber trestle seemed for some years entirely set aside, and the desire for an extreme economy superseded all other considerations in the design of iron bridges. To this period belongs a type of bridge, unfortunately not yet extinct on American railroads, in which the requirements of rigidity were almost wholly disregarded. Even for the very shortest spans the use of eyebars and rods connected by small pins was universal in the trusses, while the lateral and floor systems were connected in the loosest possible way. On a well-known Western railroad, the writer recalls examining a sixty-foot iron deck span, which was made up of some three hundred separate members and details connected by pins. The vibrations of this bridge under a moving train were quite alarming, although the sections of the truss members were in virtual agreement with the usual strain-sheet requirements.

Of late years, as is well known, the merits of plate girders for railroad work have been more fully appreciated, and this excellent form of construction has come into general use up to lengths of 80 and even 100 feet. For longer spans the riveted lattice type is constantly growing in favor, and is likely to become the standard form for all ordinary railroad bridges. The experience of those American railroads that have adhered to riveted connections from an early day has been a very satisfactory one, while European practice has been wholly on this line. It seems to the writer that this development of truss construction is the best possible one for obtaining rigidity in our bridges.

With regard to the *floor system*, it may fairly be said that its proper design is of even greater importance than that of the trusses. It is that part of the bridge with which the engine and train loading first come in contact, and all its details and connections are subjected to violent strains. It also serves to tie the two trusses together, and thus forms an important part of the lateral bracing. Any increase in the engine weights affects the short girders of the floor system far more seriously than any other part of the bridge. In fact, a decrease in the wheel base alone, without any change in the total loading, may have a dangerous effect on the floor. As an instance of this, the writer may mention a case in his practice where by merely shortening by *twelve inches* the driving wheel base of a ten-wheel engine the strains in the floor-beams and stringers were increased fully twenty per cent. For this reason the floor system is usually the first part of a bridge to be overstrained by the introduction of new types of locomotives.

The main defects of our ordinary floor systems, however, lie much deeper than in the mere scant proportioning of the sections, and are more difficult to remedy. While most floors are strong enough to carry an engine and train safely under normal conditions, few will do so when any part of the train is derailed or in "bad order." It is indeed often maintained that a bridge floor is intended to carry a train when it is on the track and not on the ties, and that the engineer's task is fulfilled when he has built a structure capable of doing so. This explanation of, or apology for, bridge failures, absurd as it is, has often been heard, even from men directly engaged in designing bridges.

The point at issue is a severely practical one. The railroad manager and the traveling public are right in asking that the railroad bridge, like any other tool, should be capable of accomplishing such work as it is liable to be called upon to do during its life.

As a matter of fact, the occurrence of a broken brake rigging or axle, a cracked wheel or a derailed truck, are conditions likely to confront it at every movement.

We cannot be asked to do what is impossible, but if a floor system can be designed which will be safe even under such untoward conditions, it is clearly our duty to provide it.

A safe bridge floor should be, what it was called by the early English engineers, a *platform*, *i. e.*, an unbroken surface from one end of the span to the other, strong enough and rigid enough to support a moving or even a derailed train at any point. If the floor meets these requirements, it will go far towards making a total collapse of the bridge structure impossible. It will, perhaps, be objected that a derailed car is likely to strike the trusses before reaching the edge of such a platform, so that it is unnecessary to provide an unbroken deck of full width. But even when this occurs, the car is sure to do less injury to the trusses, if it is properly supported on the top of the floor, than it would be when dropping through the gaps of an open or discontinuous flooring.

Even the best of our ordinary floor systems do not, in the opinion of the writer, conform fully to the requirements laid down above, while on the majority of railroads there are at least some spans with very defective floors. In the United States, timber was for a long time the sole material in use for the stringers, ties and guard-rails of bridges, and in many cases for the transverse floor-beams as well. Of late, iron rolled beams or short plate girders have replaced the wooden stringers, though for ties and guard-rails timber is still universally used. There is no doubt that with a proper proportioning and spacing of the stringers and ties, and securely fastened guard-rails, timber floors can be built which will be fairly safe as long as the timber is new. As a matter of fact, the ties are too short and spaced at too great intervals on most

bridges, while the arrangement of the guard-rails is faulty, so that a derailed train finds but little support.

To be entirely secure, there should be, at least, four lines of iron stringers, the outer ones being close to the trusses, and strong timber ties spaced very closely, preferably with openings not exceeding four to six inches. The guard-rails should consist of iron or of timbers protected by iron angles, and it is desirable to have an inner as well as an outer rail. A floor of this kind will necessarily be somewhat expensive and difficult to renew; the danger from fire will always be present, and its life will rarely exceed eight to ten years. With heavy engines, the rails are likely to cut into the ties, and the rail fastenings to become loose. As a whole, even the best timber floors will be far from fulfilling all necessary requirements as to safety and durability.

Of late years, *solid* or *continuous* floors of iron or steel have come into use on a number of American railroads, though generally only in exceptional cases. In England they have for many years been extensively employed. They consist, as a rule, of a series of troughs running transversely to the main girders or trusses, to which they are fastened. In some cases the troughs are replaced by rolled beams, closely spaced and connected by a continuous iron plate. The rails are either fastened directly to the iron troughs or to timber cross-ties. In the latter case there is often a ballast filling, so that adjustments in the track can be made by tamping.

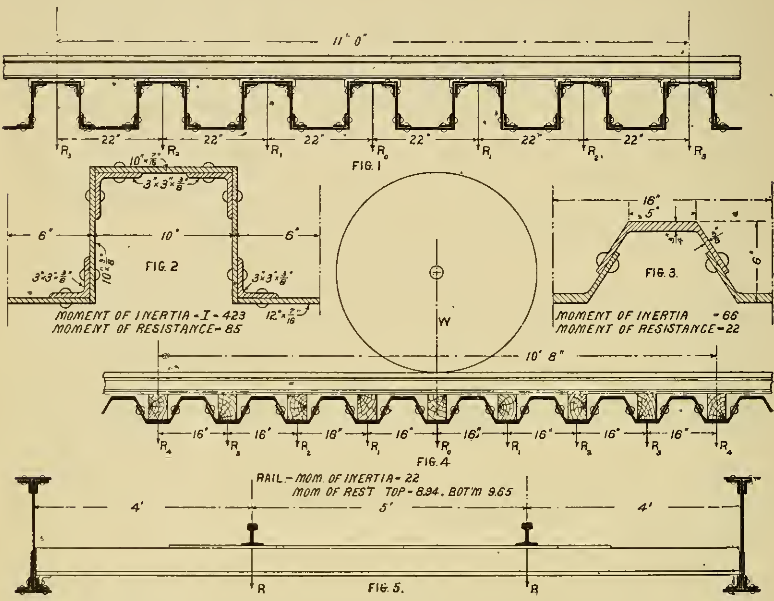
The best of these constructions possess, in the opinion of the writer, many advantages over timber floors, with but few drawbacks, while their expense is not unreasonably great. They present an unbroken platform or surface, equally strong at all points, and besides this, form a very rigid system of lateral bracing between the trusses. There is also the incidental advantage that the tracks may cross the floor at any angle, so that frogs and switch connections can be placed anywhere on the bridge. Where a very shallow floor is a necessity, the trough construction is often the only feasible form. The avoidance of fire risks is, of course, an additional recommendation for iron as compared with a timber floor.

While the solid floor is still something of a novelty in America, it is likely to be used more extensively in the future, as it possesses great merit as compared with other forms.

As a matter perhaps not devoid of interest, the writer begs to present some computations made by him on certain types of solid floor during the past year or two. It is believed that the theory of strains involved may offer some points of value, apart from its application in practical designing.

The forms selected are shown in Figs. 1 to 5, in which the

troughs with inclined sides (Figs. 3 and 4) represent the shapes used by the Illinois Central Railroad on its elevated tracks in the city of Chicago, while the square troughs were adopted by the Lake Shore and Michigan Southern and the Chicago, Rock Island and Pacific Railroads, for similar work constructed in 1894.



The mechanical theory of *least work* was first applied to the calculation of the strains in solid floors in a very interesting and valuable article on the subject, published a year or two ago, with examples from English practice.*

As in all structural work, there are two points to be determined:

(a) The maximum stress that will occur in any part of the structure under the applied loads.

(b) The deformations and deflections accompanying such strains.

The solution cannot be obtained in this case by statics alone, as it involves some considerations which belong to the theory of elasticity.

Taking the floor shown in Fig. 4, we have evidently a combination of a certain number of transverse beams 13 feet long, supported on the main girders, and two longitudinal beams, viz., the track rails. If W represents a wheel-load directly over one of the troughs, this trough as well as the rail at this point will deflect a certain amount. The rail in its turn, will depress the troughs at either side, and thus the weight

* Cf. *Engineering* (London), September 15, 1893.

W will be distributed over a number of troughs. We have, therefore:

$$W = R_0 + 2R_1 + 2R_2 + 2R_3 + 2R_4,$$

where the number of troughs to be taken into consideration depends on the relative rigidities of the rail and the troughs. The problem then resolves itself into finding out in what proportion W is carried by the different troughs; when this is known the strains in the troughs and the rails can be computed by the ordinary theory of beams.

By the *principle* of *least work* we can conclude at once that the distribution of loading will be such that the total work done in deforming the rails and the troughs will be a minimum. It remains, then, to find an expression for this work of deformation and from it to deduce R_0, R_1, R_2, etc., in terms of W. By a formula due to *Euler*, we know that, for any beam of uniform cross-section and materials

$$\text{The Work of Bending} = \frac{1}{2EI}\int M^2 dx$$

where M = Bending Moment of External Forces
E = Modulus of Elasticity,
and I = Moment of Inertia.

Applying this formula to our case.

The work of bending one trough under two loads R (Fig. 5)

$$= \frac{1}{EI}\int_0^{48} R^2 x^2 dx + \frac{1}{2EI}\int_{48}^{108} 48^2 R^2\, dx$$

Which by integration substituting for I its value $= 22$

$$= 1606 \frac{R^2}{E}$$

This formula may be proved as follows:

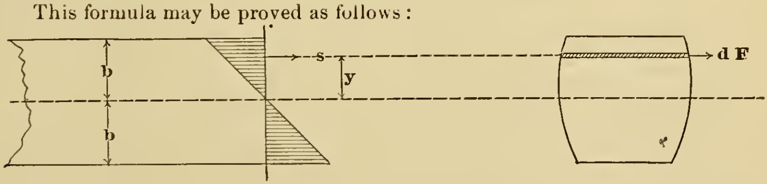


FIG. 6.

If Fig. 6 represents a beam cut at any point,
Let dF = an elementary area at a distance y from the central axis.
s = unit strain on dF.
Then sdF = total force acting on dF.
$\frac{sdx}{E}$ = elementary distance passed over by this force; and work done =

$$\tfrac{1}{2}\, sdF\, \frac{S}{E}\, dx$$

which for the whole cross-section =

$$\frac{1}{2EI}\, M^2 dx.$$

This expression when integrated for any given length of the beam gives the form in the text.

Hence if U_T = work of bending all the troughs

$$U_T = \frac{1606}{E} (R_0{}^2 + 2\, R_1{}^2 + 2\, R_2{}^2 + 2\, R_3{}^2 + 2\, R_4{}^2)$$

Or, by substitution, since $R_0 = W - 2\, R_1 - 2\, R_2 - 2\, R_3 - 2\, R_4$

$$U_T = \frac{1}{E} (1606\ W^2 + 9636\ R_1{}^2 + 9636\ R_2{}^2 + 9636\ R_3{}^2 + 9636\, R_4{}^2 + 12848\, R_1\, R_2 + 12848\, R_1\, R_3 + 12848\, R_1\, R_4 + 12848\, R_2\, R_3 + 12848\, R_2\, R_4 + 12848\, R_3\, R_4 - 6424\ WR_1 - 6424\ WR_2 - 6424\ WR_3 - 6424\ WR_4).$$

Again from formula (A):

If U_R = work of bending the two *rails*,

$$U_R = \frac{2}{EI} \left(\int_0^l M_1{}^2 dx + \int_0^l M_2{}^2 dx + \int_0^l M_3{}^2 dx + \int_0^l M_4{}^2 dx. \right)$$

Where $M_1\ M_2\ M_3\ M_4$ are bending moments in the different panels of the rail.

The rail is here a continuous girder with reactions at the supports $= R_0$, R_1, R_2, R_3 and R_4, respectively, so that we can write

$$M_1 = R_4\, x$$
$$M_2 = R_4\, l + R_4\, x + R_3\, x$$
$$M_3 = 2\, R_4 l + R_3 l + R_2\, x + R_3\, x + R_4\, x$$
$$M_4 = 3\, R_4 l + 2\, R_3 l + R_2 l + R_4\, x + R_3\, x + R_2\, x + R_1\, x$$

where l = the panel length = 16 inches.

By reduction we have:

$$U_R = \frac{1}{E} (3972\, R_4{}^2 + 1676\, R_3{}^2 + 497\, R_2{}^2 + 62\, R_1{}^2 + 1738\, R_2 R_3 + 497\, R_1\, R_3 + 310\, R_1\, R^2 + 5027\, R_3\, R_4 + 2483\, R_2 R_4 + 683\, R_1\, R_4).$$

Hence if $U = U_T + U_R$ = total work done.

We can write:

$$U \frac{1}{E} (1606\ W^2 + 13608\, R_4{}^2 + 11312\, R_3{}^2 + 10133\, R_2{}^2 + 9698\, R_1{}^2 + 13158\, R_1\, R_2 + 13345\, R_1\, R_3 + 13530\, R_1\, R_4 + 14586\, R_2\, R_3 + 15331\, R_2\, R_4 + 17875\, R_3\, R_4 - 6424\, WR_1 - 6424\ WR_2 - 6424\ WR_3 - 6424\ WR_4)$$

This is a function of $R_4\ R_3\ R_2$ and R_1 and will be a minimum when all the partial derivatives are equal to zero.

Differentiating we have:

$$\frac{dU}{dR_4} = \frac{1}{E} \left(27216\, R_4 + 17875\, R_3 + 15331\, R_2 + 13531\, R_1 - 6424\, W \right)$$

$$\frac{dU}{dR_3} = \frac{1}{E}\left(17875\,R_4 + 22624\,R_3 + 14586\,R_2 + 13345\,R_1 - 6424\,W\right)$$
$$\frac{dU}{dR_2} = \frac{1}{E}\left(15331\,R_4 + 14586\,R_3 + 20265\,R_2 + 13158\,R_1 - 6424\,W\right)$$
$$\frac{dU}{dR_1} = \frac{1}{E}\left(13531\,R_4 + 13345\,R_3 + 13158\,R_2 + 19396\,R_1 - 6424\,W\right)$$

Equating these to zero and reducing we have:

$$\begin{aligned}
424\,R_4 + 279\,R_3 + 239\,R_2 + 210\,R_1 &= 100\,W \\
279\,R_4 + 362\,R_3 + 227\,R_2 + 208\,R_1 &= 100\,W \\
239\,R_4 + 227\,R_3 + 316\,R_2 + 205\,R_1 &= 100\,W \\
210\,R_4 + 208\,R_3 + 205\,R_2 + 302\,R_1 &= 100\,W
\end{aligned}$$

These simultaneous equations may be solved without any especial difficulty and give:

$$\begin{aligned}
R_0 &= .192\ W. \\
R_1 &= .173\ W. \\
R_2 &= .120\ W. \\
R_3 &= .080\ W. \\
R_4 &= .031\ W.
\end{aligned}$$

By the same method we get for the second type (Figs. 1 and 2):

$$\begin{aligned}
R_0 &= .39\ W. \\
R_1 &= .26\ W. \\
R_2 &= .09\ W. \\
R_3 &= -.045\ W.
\end{aligned}$$

Having thus obtained the proportion of a single concentrated load carried by the different troughs, the calculation may readily be extended to any system of axle loads desired.

In practice the driving-wheels of engines are rarely less than five feet apart, and we may suppose a wheel to be placed at every fourth trough in Fig. 4, or every third trough in Fig. 1.

Combining the percentages of W, which are thus concentrated on the different troughs, we find that the distribution of the loading over all the troughs of the floor will be nearly uniform. In other words, in the first case each trough carries one quarter of the wheel load, and in second case, one third. These results enable us to compute the greatest strains likely to occur in any one trough with a degree of accuracy fairly comparable with that obtained in the other parts of bridges. It may indeed be objected that the stiffness of the rail is depended upon to a greater degree than is proper, but it is doubtful whether the conditions under which the rail acts on a bridge of this kind are not more favorable to its life than those met with on the rest of the road-bed.

A further point has been raised as to the effect of an inefficient rail joint on the distribution of the loading. Some computations have been made by the writer on this point. In order to make the case as unfavor-

able as possible, the joint plates have been supposed to be entirely removed. The result of the computation indicates that even in this case the maximum load on a trough is but slightly increased over the proportions tabulated above.

In some cases, moreover, additional iron rails, or deck beams and angles, have been used as guard-rails, which are of course quite efficient in distributing the load longitudinally.

It is beyond the scope of this paper to discuss at length the different forms of solid floors or their relative strength.

The question of depth is often decided by local considerations which govern special cases. As shown by a comparison of the two cases considered above, the shallower floors distribute the loading more widely and thus reduce the strains and lead to an economy of material. They are, however, not very stiff under trains, and this lack of rigidity, though perhaps advantageous to the rolling stock, may tend to loosen the rivet connections or even the track fastenings. The deeper floors concentrate the loading so that each trough contains more metal, and the floor is made more rigid even if it is not stronger than one of lesser depth.

It seems advisable on the whole not to go below a depth of nine or ten inches for the floors of single-track bridges, at least under such heavy train-loads as must usually be provided for.

DISCUSSION.

Mr. Wallace.—Mr. Goldmark has evidently overlooked the fact that the C. M. and N. Division of the Illinois Central has five bridges, having the style of floor mentioned in the first part of his paper, or a similar style, that have been in service five years. This floor was designed, under the general direction of Mr. E. L. Corthell, by Mr. A. F. Robinson, and was used in five bridges on what is known as the Clyde viaduct, where the Illinois Central crosses the Chicago, Burlington and Quincy Railroad, west of the city. One of these bridges is a 150 feet span; the other four are plate girders. The depth of the trough was 12 inches, and made substantially square, as shown on drawings. The tie, however, rests on a reversed angle placed 6 inches below the top of the trough; the tie being 8 inches in thickness, the rail rests on the tie, clearing the ironwork 2 inches, the tie serving as a cushion between the bridge floor and the rail. This floor is very stiff and has given satisfactory results. This trough section of floor (indicated on drawing), the design mentioned by Mr. Goldmark as being used on the bridges over the streets on the Illinois Central elevated work through Hyde Park, was adopted on account of its being a commercial section that could be easily and quickly procured; as, after the railroad company decided to do this work

there only remained nine months to design and construct the bridges, and it was found the work would be delayed in case any other design was used. It was therefore not considered advisable to make a special design and run the risk of delay.

In the original plan the ties rested on the bottom of the troughs, as indicated by Mr. Goldmark, it being the intention to bed the ties in a preparation of asphalt or asphalt concrete, in order to deaden the noise and preserve the ties. It was afterwards found, however, that this work could not be contracted for at less than $1.25 or $1.50 per tie, and that no track could be spared from service for our own men to do the work, and the plan was abandoned, the ties being permitted to rest on the bottom of the troughs as indicated in the drawings. The ties are now being taken out of the troughs and shifted so as to rest on top of the sections, enabling the troughs to be regularly cleaned out and properly painted.

While these floors have given very satisfactory results, and after sixteen months' hard usage we have found no loose rivets, the present plan will add strength to the floor, and is expected in some measure to relieve the strain on the rivets. Our fast suburban trains are now passing over this floor at 10 to 15 minutes intervals and at speeds of from 45 to 50 miles an hour. The traffic on the other tracks is heavy and continuous.

The additional reason we had for taking the ties out of the troughs and putting them on top of the sections was to relieve the rail from the liability of contact with the iron by cutting into the ties, as when the ties remained in the troughs there was only a fraction of an inch clearance, and as we are using the track circuit for the operation of our block signals the rail coming in contact with the iron would interfere with the satisfactory operation of these signals.

Mr. W. R. Roberts.—I would like to ask how high the ties are?

Mr. Wallace.—Six inches.

Mr. Bainbridge.—I would like to ask if you have any trains off the tracks under those conditions?

Mr. Wallace.—No.

Mr. Roberts.—I would like to ask what the deflection was?

Mr. Goldmark.—In this case the deflection was less than half an inch.

Mr. Roberts.—That is under the rail?

Mr. Goldmark.—Yes.

Mr. Lundie—In Mr. Goldmark's equation he equates the work done by W to the work done by rail and troughs. There is the work done by the girders, the structure being elastic and having deflection, Now, do you take any account of the ties, or do you consider they distribute the work uniformly along the troughs. Will not that form an important element in figuring the deflection?

Mr. Goldmark.—It would, but the deflection is so slight, I did not introduce the deflection in the calculation of that work at all.

Mr. Lundie.—Take the work of the tie, will it not affect the result?

Mr. Goldmark.—Yes; but it will be favorable; the deflection will be even less.

Mr. Wallace.—I understand that you did not take into consideration the work of the tie itself at all?

Mr. Goldmark.—No; I did not. That would make each girder a little bit stronger than it would be otherwise. Just how much I do not think it would be easy to say, but it will make all the expressions a little stronger.

Mr. Wallace.—In connection with the ties I would like to make this remark, that the girders along the Illinois Central are generally placed 13 foot centers, and several times we have changed our tracks from one space to another, and in one case we were not able to get our iron floors for them, and we support our tracks over these openings by stringers, which are virtually ties, resting on the flanges of the girders here (indicating shelf angles), and not having solid floors. We are using 12 x 12 and 8 x 16-inch ties, they are ties or floor-beams, whatever you may call them, resting on the bottom flange here. (Indicating shelf angles.)

Mr. Horton.—I wish to place myself on record in support of Mr. Goldmark's suggestion that bridge designs should be simple, using material from the rolls in large sizes rather than small. If a flange of a girder requires a total section not exceeding what may conveniently be procured in two angles, use two angles only. Relieve the girder of stiffeners; except where there is some reason to suppose they are useful. Put the weight of useless stiffeners into extra thickness of web or other parts, to the end; that the structure shall be better prepared to resist shocks as well as destruction caused by rust.

Following this line of thought, I think a clause introduced in specification, requiring all metal to be at least ½ inch thick, would be in the right direction. Mr. Goldmark's investigation would lead to the conclusion that the quite general specification (for timber ties laid on stringers, say, 1 foot 4 inch centers), that three ties be assumed to carry a full wheel load, is satisfactory, in fact fully justified by the investigation.

In the solution of equations as they appear from Fig. 4, and assuming an additional wheel load placed at R_4, both right and left, we discover that the rail is called upon to act as a continuous beam 5 feet 4 inches between supports, resulting in nearly equal distribution of the load on the points R_0 R_1 R_2 R_3 R_4.

With a wheel load of 36,000 pounds at R_0, and also at R_4, both

right and left, we shall have at R_0 9,144 pounds; at R_1 9,108 pounds; at R_2 8,640 pounds, and at R_3 9,108 pounds, aggregating one wheel load. That is, with the assumed rail section and assumed floor (precession of wheels quite as actually used), a variation is shown in the load on all the troughs of only 504 pounds. If this is a fact it appears the rail is called upon to do a very considerable amount of labor as a beam.

The two solid floors shown have taken very different directions in design, one using ties of timber, in the other, rails being secured directly to the metal work. Also attachment of floor to girder is one of further radical difference; one rests upon shelf angles, the other has connecting angles with oblique gussets.

Another point in connection with the solid floor. Shall the floor be water-tight, as in the two examples shown by Mr. Goldmark? My attention has been called to a track elevation ordinance in another city, where it is specifically stated that the floor shall be open to allow light to pass through. The open construction will more than likely be most in favor as best serving all questions of stability as well as durability

It is my understanding that solid floors, as used in Europe and generally in this country up to the present time, have had track with ties, with or without ballast. The tendency to rust under the ties and ballast without chance for inspection has developed a modified design.

The distance from base of rail to clearance, where solid floors are used, is material, the demand in most cases is for very narrow limits.

Some months since I had occasion to work out a solid floor, using I-beams—the sketch shows the design—the flange of the I-beams, top and bottom, being open for inspection.

Considering the I-beam in connection with the various requirements for solid floors: It will allow the floor to be as shallow as any section. It may be an open construction by simply leaving out the concrete filling, or water-tight with the filling. It may be set on shelf angles or secured by conneting angles, or carried by oblique gussets. It will take less pounds of material than any other form suggested. It will require materially less work in the shop, and certainly no more in the field than the various other methods proposed.

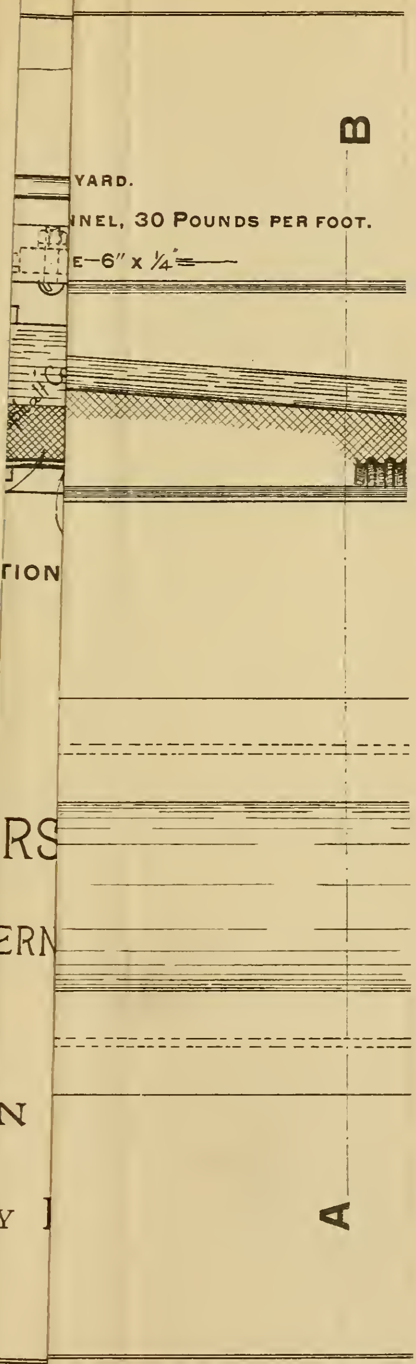
Indurated fibre between the rail and the channel is proposed, first to reduce the wear on the rail fastenings, second, to reduce noise. The continuous splice bars are proposed as somewhat of a safeguard against a broken rail.

It may be urged that I-beams spaced anywhere from 12 to 18 inches center to center, the flange of the beam reducing the space at least 5 inches, does not make a very solid floor; however, as the openings are necessarily at right angles to the direction of traffic, a wheel off the track will roll better across openings of 12 inches than of 12 feet.

With I-beams it is entirely feasible to rivet plates the entire width and length of structure on the top flange of beams, making a solid surface for a derailed train, or the plate may be riveted on the bottom flange. In fact, the I-beam, or the I-beam in combination with plates, furnishes material in shape to form support of track without ties, with greater economy than any other form suggested. It may be a misfortune that there is no patent connected with its use, because if backed by patent it would be promoted.

Mr. Goldmark's conclusion that the more elastic floor has advantages in distributing load is true with continuous rail of certain stability acting as a continuous beam; however, there must be limits as to the elastic floor's advantage for distributing weight through the rail, because the rail is of uncertain rather than certain stability, and is not continuous.

ATIC H. E. HORTC



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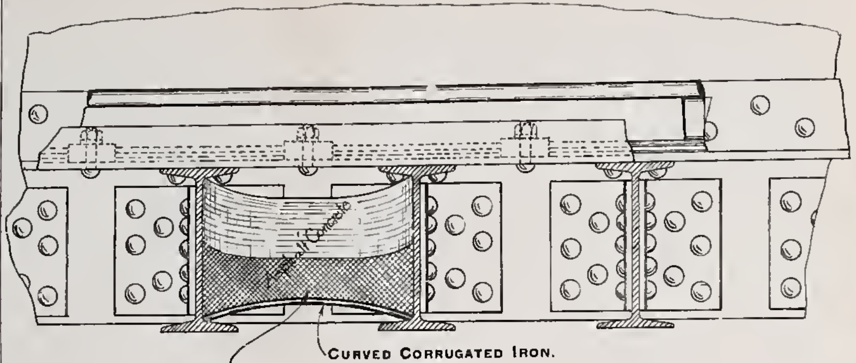
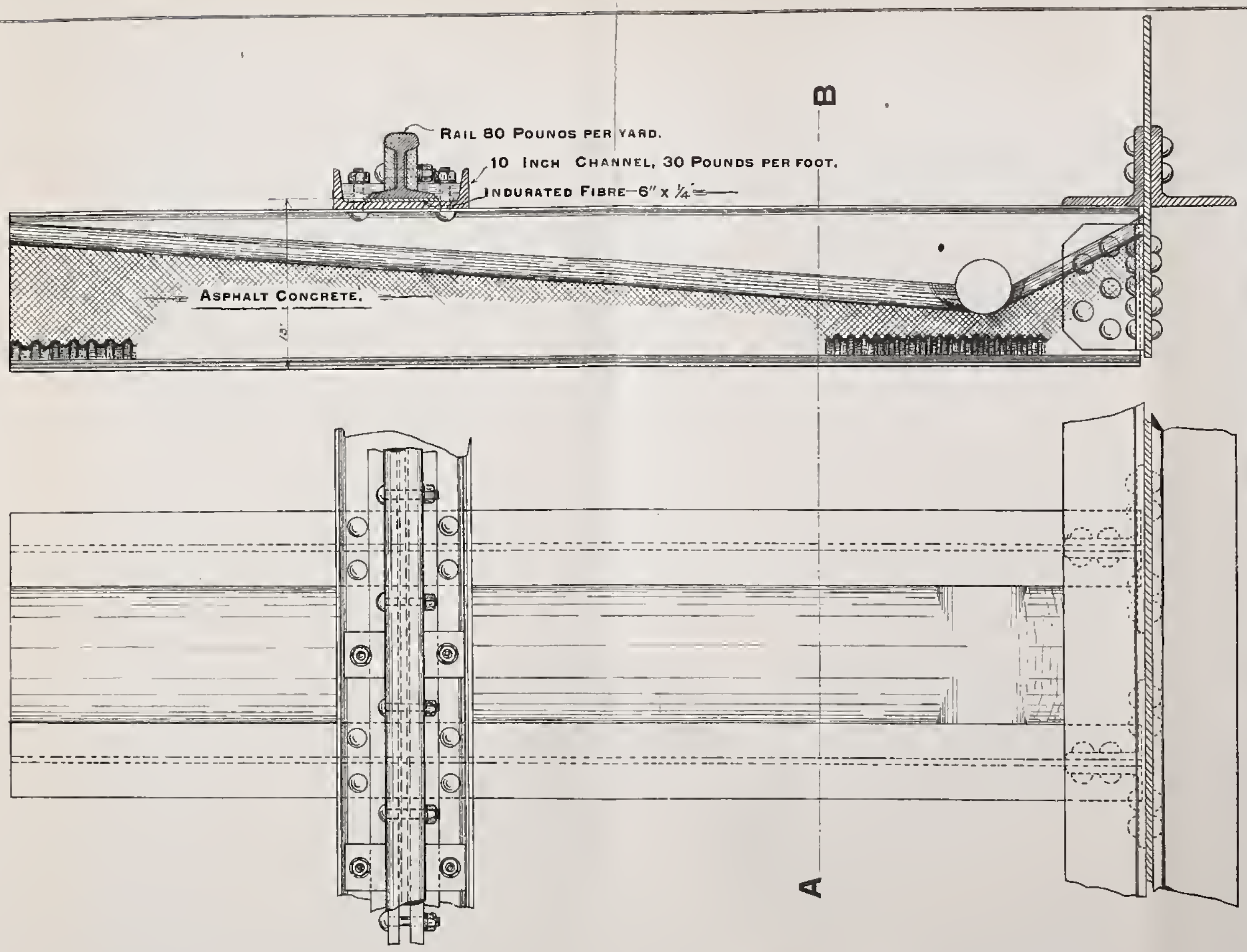


SECTION ON A-B.



SOLID FLOORS FOR RAILROAD BRIDGES

WESTERN SOCIETY OF ENGINEERS

DESIGN FOR SOLID FLOOR

By H. E. HORTON

THE DE KALB ELECTRICAL PUMPING PLANT.

By Daniel W. Mead, Member of the Western Society of Engineers.

[Read before the Society, May 14, 1895.*]

De Kalb, Ill., is a city of about 5,000 inhabitants and lies on the main line of the Chicago and North Western Railway about sixty miles west of Chicago. De Kalb has had a system of water works since 1879, but as it was the result of circumstances rather than intelligent design it was far from satisfactory. In 1872 the agitation in favor of water works first began and a deep well 4½ inches in diameter was sunk to a depth of 1,000 feet. No flowing water was obtained and the well was considered practically a failure, although a pump and wind mill was soon after erected.

In 1878 it was decided to drill deeper in the hopes of striking flowing water, and another well 4½ inches in diameter was sunk to a depth of 2,469 feet, but no flowing water was encountered.

The failure to secure flowing water at De Kalb is due to the fact that De Kalb is one of the highest points in Northern Illinois. The surface at the location of these wells is about 897 feet above sea level, while the artesian waters at Rockford, about thirty miles northwest of De Kalb, have never risen from the Potsdam sandstone to a higher level than 741 feet above the sea, or from the St. Peter sandstone to about 705 feet above sea level. The water in the De Kalb wells, however, now stands at about 772 feet above sea level, or about 125 feet below the surface of the ground at the old pumping station, which is much higher than would be expected from results obtained in other places.

In 1878 a contract was made for an engine, boilers and elevated tank, and the first public supply for fire purposes dates from the completion of this contract in 1879. The wells as drilled were found to be too small, and in 1882 a 6-inch well was drilled 800 feet deep to the St. Peter sandstone, and a Deane direct-acting steam deep-well pump was purchased to raise water from this well. A standpipe 22 feet in diameter and 80 feet high was also built in 1890, and into this the deep-well pump raised the water. The water mains consist of about 2,500 feet of 6-inch cast-iron pipe and about 24,000 feet of 4-inch cast-iron pipe, with numerous hydrants and a very few valves.

On May 29, 1893, the City Clerk reported the cost of the water works plant to be as follows:

* Manuscript received July 17, 1895.—*Secretary, Ass'n of Eng. Socs.*

First well	$4,050 00
Second well	14,450 00
Engine, boiler and tanks	4,279 50
Third well	4,000 00
Standpipe	8,000 00
Pumps, heaters, etc.	2,790 49
Hydrants and mains	19,385 45
Interest on bonds	8,046 88
Total cost	$65,002 32

The cost of operating the works for the two years prior to the construction of the new plant was as follows:

	From May, 1892, to May, 1893.	From May, 1893, to May, 1894.
Engineer and assistant	$1,140 00	$1,381 40
Repairs and supplies	323 62	266 00
Extra labor	70 65	70 35
Incidentals	30 55	....
Electric light	108 53	113 12
Coal	$1,350 71	2,019 80
Total operating expenses	$3,023 52	$3,850 67
Revenue	2,637 97	2,715 17
Deficiency	$385 55	$1,135 50

The average pumping record was as follows during this time:

Hours pumped per day	15	22
Gallons pumped per day	85,260	98,652
Cost per 1,000 gallons pumped	9.8 cents.	10.8 cents.

Cost of coal about $2.40 per ton of 2,000 pounds.

From the above it will be seen that while the revenues were not materially increasing, the operating expenses were rapidly increasing, and the cost of pumping per 1,000 gallons had increased about 10 per cent. The plant was in operation an average of twenty-two hours per day through the years 1893 and 1894, and during the warm weather it ran continuously, except when necessary to shut down for repairs. In the extremely dry summer weather it became necessary to shut off the water entirely, with the exception of an hour each at morning, noon and night, in order that water might be kept in the standpipe for fire purposes.

These were the circumstances when the writer was called in to suggest some remedy whereby a sufficient amount of water could be secured and the works put on a paying basis.

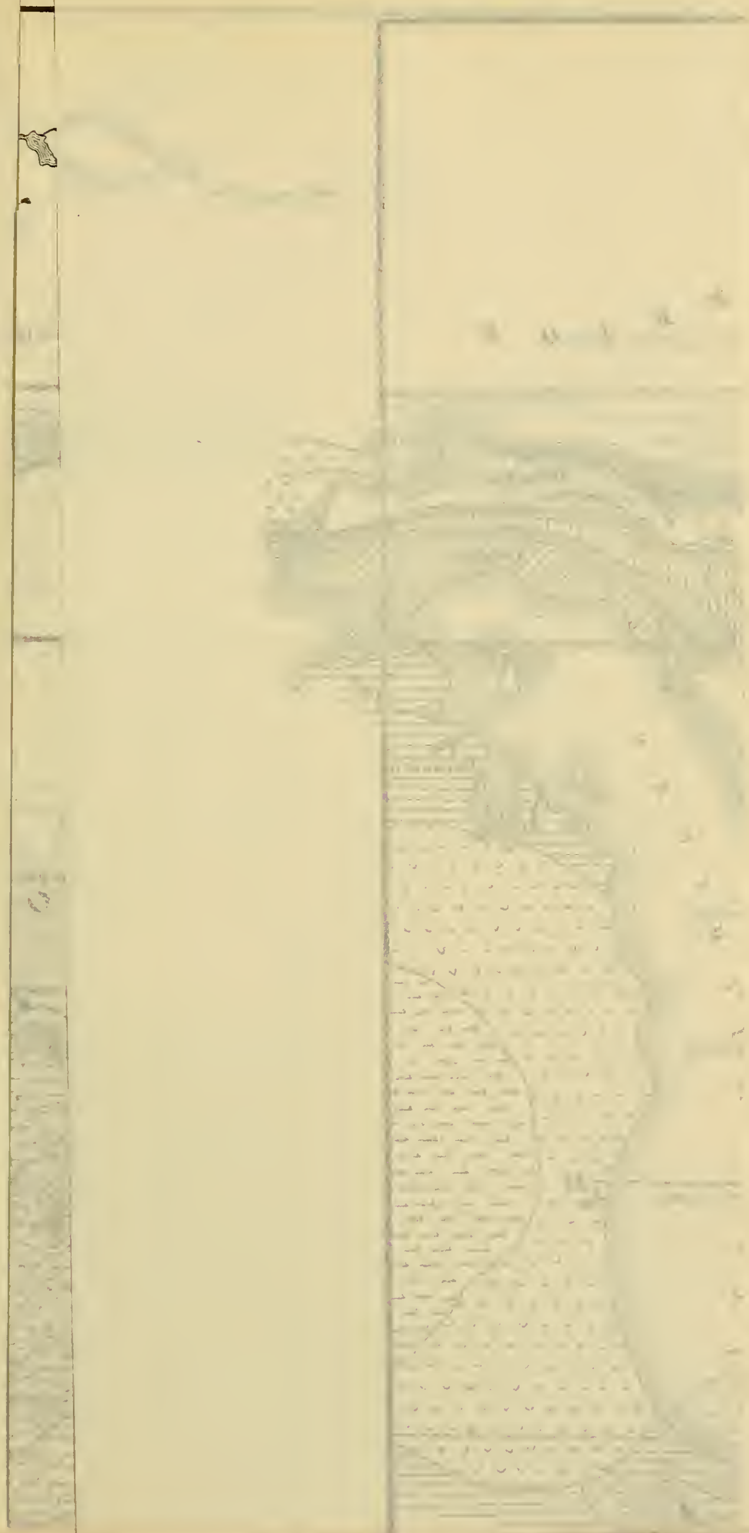


FIG. 1.—APPROXIMATE GEOLOGICAL MAP OF UPPER MISSISSIPPI VALLEY, SHOWING LOCATION OF DE KALB AND SOURCE OF ITS WATER SUPPLY.

AVAILABLE SOURCES OF WATER SUPPLY.

De Kalb is situated on a branch of the Kishwaukee River, which is there, however, very small, and is dry during the summer months. No drainage areas are readily available for collecting and impounding water, as the land is quite level for a large distance in every direction from the city. In consequence the city has to depend on the underground waters for its supply.

In all cities of Northern Illinois there are three sources which can usually be made available with more or less success as sources of water supply. These are:

1. The sands, gravels and clay drift which overlie the bed rock.
2. The St. Peter sandstone.
3. The Potsdam sandstone, which contains the lowest water-bearing strata.

The waters from the St. Peter and Potsdam sandstones fall as rain in Wisconsin on the exposed outcrop of these strata, which is there at a higher elevation than most of the surface of the ground in Illinois. Sinking into these strata, which have a southerly dip, the waters flow south and are reached by the drill at various points southerly from their outcrop, under considerable hydraulic pressure, in many cases giving rise to flowing artesian wells. (See Hydro-Geology of Upper Mississippi Valley, JOURNAL ASSOCIATED ENGINEERING SOCIETIES, July, 1894). The drift waters have a similar origin. Their watersheds are not, however, so marked and obvious, but are often more local and limited in extent. The map and profiles will make the sources and general conditions of these waters easily understood. (See Fig. 1.)

At De Kalb a number of private wells have been sunk into the drift, some of which give flowing waters. The water obtained, however, is quite hard and not as suitable for domestic and boiler use as the water from the St. Peter sandstone, as the following analyses, made by G. M. Davidson, Chemist, will show:

	Drift Water.	St. Peter Water.
Total solids	47.59	17.49
Carbonate of lime, ...	16.66	8.37
Carbonate of magnesia, ...	6.29	6.47
Sulphate of lime, ...	4.39	. .
Sulphate of magnesia, ...	12.25	. .
Oxide of iron and alumina, ...	11.12	.69
Silica, ...	.87	. .
Alkaline chlorides, ...	2.33	.11
Alkaline sulphates, ...	4.68	1.13

The Potsdam waters are only obtained by drilling considerably deeper than for the St. Peter waters, and as the previous experience of the city did not show that any advantage was to be gained by the extra

expense involved in deep borings, the St. Peter water was selected as the source of supply for the city.

The old pumping plant was practically of no value. It had been erected on the highest ground in the city and all coal had to be hauled to it at an extra expense. The machinery was worn out or inadequate. The wells at that point were also too small to be available for the increased supply. It was therefore decided to sink a new well near the crossing of the Chicago & North Western Railway with the Kishwaukee River, where the ground was about 855 feet above sea level. The well was designed to be 14 inches in inside diameter to the rock and 6 inches in diameter in the rock to and into the St. Peter sandstone. The contract was let to W. H. Gray & Bro., of Chicago, for 14-inch casing

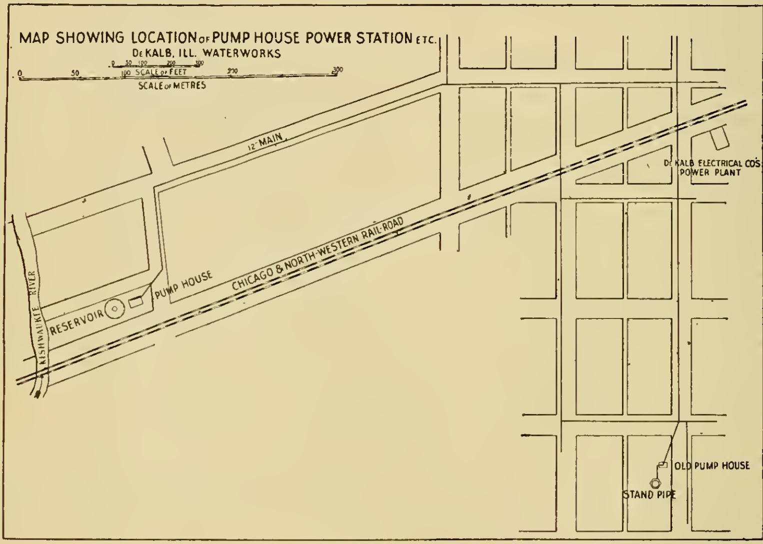


FIG. 2.

to the rock at $4.00 per foot, and a 6-inch hole in the rock at $1.95 per foot. The well drillers had great difficulty in sinking the 14 inch pipe to the rock, and were permitted by the city to reduce it at 128.4 feet below the surface, from which point to the rock 161 feet below the surface it is 12 inches in diameter. The entire depth of the well as completed was 890 feet, and the water rose to within 65 feet of the surface.

The strata encountered in drilling the well were approximately as follows:

0 to 125 feet, clay.
125 to 145 feet, sand, clay and quicksand (water-bearing).

145 to 161 feet, clay and sand (water-bearing).
161 to 265 feet, limestone.
265 to 285 feet, soft limestone.
285 to 520 feet, limestone.
520 to 525 feet, layer of sandstone.
525 to 535 feet, shale.
535 to 595 feet, sandy shale.
595 to 890 feet, St. Peter sandstone (water-bearing).

It was originally intended to erect a steam plant for the new pumping works, but as the De Kalb Electrical Company made the city of De Kalb a favorable proposition for operating the works; and the ex-

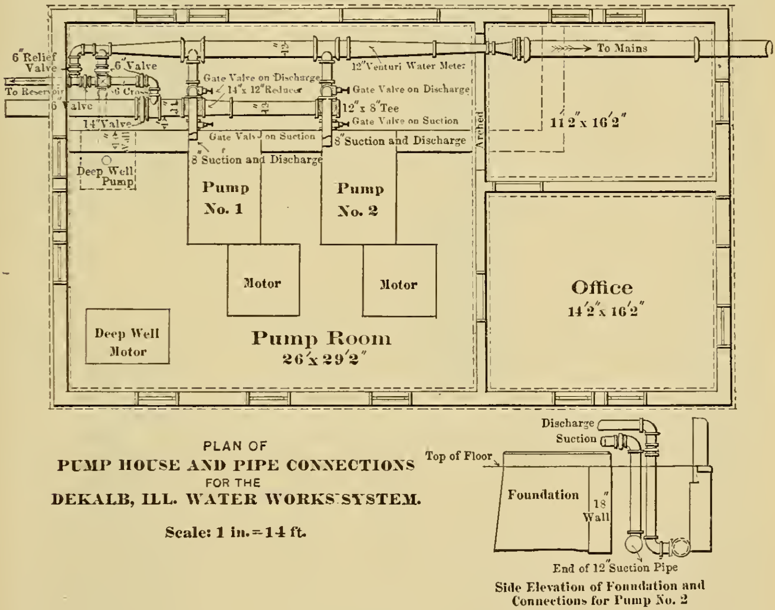


FIG. 3.

perience of the city in the management of its own works was not such as would warrant expectations of economical management in the future, it was finally decided by the City Council to contract with the De Kalb Electrical Company to do the pumping for the city for a period of ten years, and the plant was designed and built on this basis.

At the site of the well was erected an inexpensive brick pump-house, divided into a pump-room with an alcove storage-room and a small office.

Within 30 feet of the pump-house is built a storage reservoir which is also of brick, 65 feet in inside diameter, 22 feet in extreme depth and of a capacity of 500,000 gallons. A wall 2 feet in thickness and 6 feet

in height is built across the center of the reservoir, dividing it into two portions, so that water can be pumped into or out of either or both sides, and with a valve located at the further end of the cross wall. A circulation can thus be maintained and any sand pumped from the well will be deposited in the reservoir instead of in the mains. The roof is a conical truss roof, supported only at the walls. The water is to be pumped from the deep well into the reservoir by a deep-well pump of a capacity of 300 gallons per minute, run by a 25 horse-power motor. From the reservoir the water is taken by either or both of two service pumps, each of a capacity of 500 gallons per minute and each operated by a 50 horse-power motor, and forced through the mains into the stand-pipe or, in case of fire, by direct pressure into the mains. The plan of the foundations and piping (Fig. 3) will make the general arrangement plain.

At the time of completing the well, a test was made as to its capacity for furnishing water, and it was found that in pumping at the rate of 300 gallons per minute the surface of the water would descend, from its stationary position, 65 feet below the surface, to a depth of 165 feet below the surface. Consequently the deep-well pump cylinder was placed 161 feet below the surface with a 6-inch suction pipe 25 feet in length below it.

In selecting a deep-well pump for the service required much trouble was encountered in obtaining what was desired. Very little attention has apparently been given by manufacturers to developing efficient pumping machinery for raising the largest possible amount of water out of deep bore holes, and few of the manufacturers were found who would guarantee the efficiency of their pumps. Most of the pumps offered were single acting. That is, they performed practically all of the work on one-half of the revolution. And, to attain the capacity desired, this involved a large pump cylinder, and a very uneven distribution of power. It involved also considerable loss of work in raising the long and unbalanced pump-rod at each stroke. The ordinary form of deep-well valve consisting of a spherical brass ball seated in a ground brass seat and having a very limited rise, had not been found satisfactory at the old works and a better arrangement of valves was also desired. Only one of the pumps offered gave any promise of the desired results, and this was offered by the Downie Pump Company. This pump consisted of a double-acting pump-head and the Downie water cylinder and patent conical valve. The valve possessed a number of admirable features, among which may be named large water way and simplicity of construction, and it was adopted unchanged. (See Figs. 4 and 5.)

The Downie power pump-head as originally submitted, while containing the principle most satisfactory to the writer, was not satisfactory in the details of design or construction. A modified form

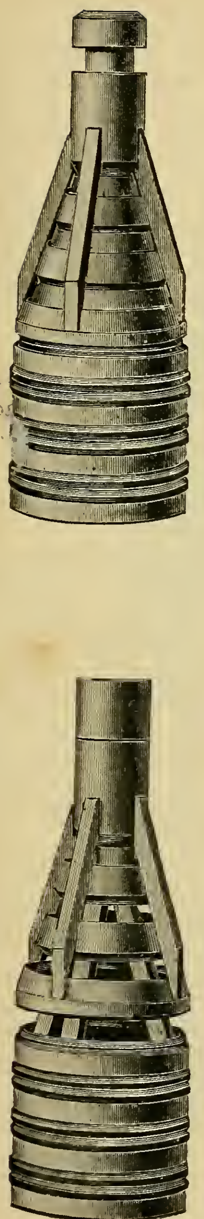


FIG. 4.

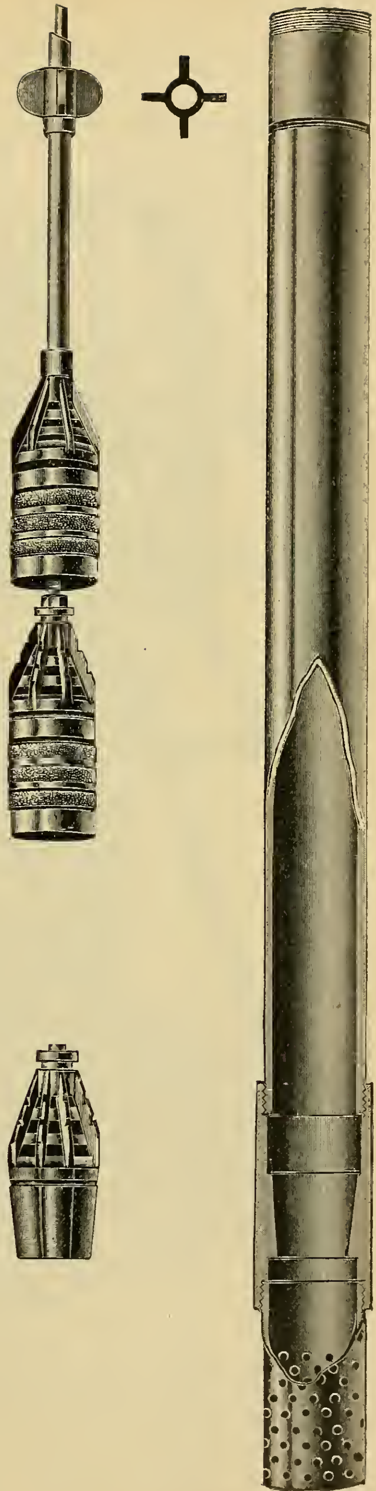


FIG 5.

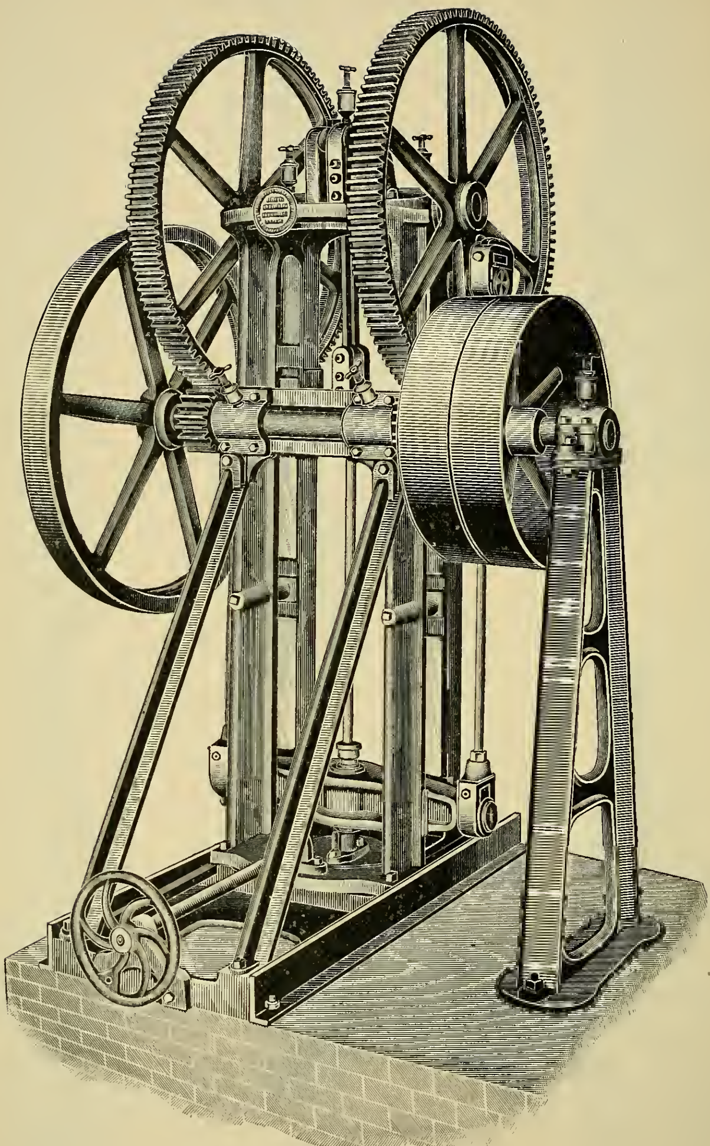


FIG. 6.

of the Downie pump was finally designed by the writer, but has not yet been constructed.* A temporary pump is now at work, while the new pump is being built by this company. This pump is expected to give an efficiency of about 65 or 70 per cent. The deep-well pump is connected to the motor by a 12-inch belt. The motors were furnished by the General Electric Company.

There are two multipolar motors of 50 horse-power each, at 200 volts, to operate the service pumps, and one multipolar motor of a capacity of 25 horse-power at 220 volts, to operate the deep-well pump.

The motor rating is on the basis of the mechanical horse-power delivered by the armature shaft at pulley or pinion of same. The field cores and frames of the motors are of cast steel.

Their armatures are of the "iron clad" type, wound with machine-formed coils, and are interchangeable and separately insulated. These coils are placed in slots in the armature punches in such a manner that should a coil become injured in any way, it may be readily replaced without disturbing the rest of the winding.

These motors are sparkless during changes varying from full load to no load, and the design is such that changes varying from full load to no load can be made without varying the position of brushes. The motors are so designed that when running at their normal load the rise in temperature in any part, above the surrounding air, will not be more than 100° Fahrenheit.

It was required that the speed of the 50 horse-power motors should not be greater than 495 revolutions per minute, at 200 volts, and the speed of the 25 horse-power motor should not be more than 565 revolutions per minute at 220 volts.

The motors have a guaranteed efficiency of not less than 90 per cent. at full load, and not less than 82 per cent. at one-half load; and were to be capable of carrying 25 per cent. over-load for a period of eight hours without injury.

These motors were designed and constructed for this particular work, and the motor of the east pump was tested for efficiency with the following results. This motor was disconnected from the pump. A split iron pulley was fastened to the shaft for use as a brake pulley, and to this a friction brake was attached. The pulley which was furnished by the city did not fit the shaft well and was therefore not perfectly true in circumference. For this reason it was impossible to make an absolute measurement of the maximum power of the motor; for at the higher

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* Since writing the above, a pump, modified somewhat from the writer's design, has been furnished the city of De Kalb by the Downie Pump Co. and is now on trial. The pump is shown in Fig. 6.

powers the irregularity in the pulley rim caused the brake to become unsteady and the weight necessary to balance it could not be determined with sufficient accuracy. Enough measurements were made, however, to give data for determining the curve of efficiency of the motors, from which the efficiencies at the limits of the capacity of the motor were calculated. The following table, which represents the average of a number of measurements, shows the results obtained:

TEST OF MOTOR ON EAST PUMP, DE KALB PUMP HOUSE.

Time from	10.34	10.46	11.38	2.02
Time to	10.44	10.56	11.45	2.18
Amperes	95.4	106.5	157	16⅓
Volts	218.7	216	199	217¾
Watts	20864	23004	31243	3557
Electric H. P.	27.98	30.84	41.88	4.76
Revolution of motor per minute	399	396	402	379
Weight on brake arm	113	123	154	No load.
Weight of brake	35¼	35¼	35¼	
Corrected weight	77¾	87¾	118¾	
Length of brake arm	4 ft.	4 ft.	4 ft.	
Brake H. P.	23.59	26.41	36.28	
Efficiency	84.3	85.63	86.86	

From these experiments the following approximate average efficiencies under various loads were calculated:

H. P. Furnished to Motor.	Calculated Efficiency of Motor.	Guaranteed Efficiency.	H. P. Delivered to Pump.
25	83.56		20.89
30	84.81	82	25.44
35	86.16		30.15
40	87.41		34.96
45	88.66		39.90
50	89.81		45.08
55	91.06	90	50.08
60	92.31		55.39

From the data obtained it will be seen that it took 4.76 horse-power to run the empty motor; of this .75 horse-power was ascertained to be consumed in the field wires. The writer had the assistance of Mr. J. W. Glidden, Superintendent of the De Kalb Electrical Company, in the selection and arrangement of the electrical features of the plant.

The service pumps (see Figs. 7 and 8) were furnished by the Gould Manufacturing Company, of Seneca Falls, N. Y., through their Chicago office. This company also had the contract for furnishing the motors and fittings. The pumps consist of two vertical triplex single-acting power pumps, having plungers 10 inches in diameter and a stroke of 12 inches. The approximate weight of each pump is about 18,000 pounds. The connecting rods are joined to the plungers by cross heads, which are outside guided. All bearings are of phosphor bronze. The pinion shaft is of machine steel, is 3 inches in diameter and runs in two bearings

12 inches in length. The crank shaft is forged steel, the main bearings being 6 inches in diameter by $15\frac{1}{2}$ inches in length. The pumps are arranged throughout so that all parts are readily accessible and all

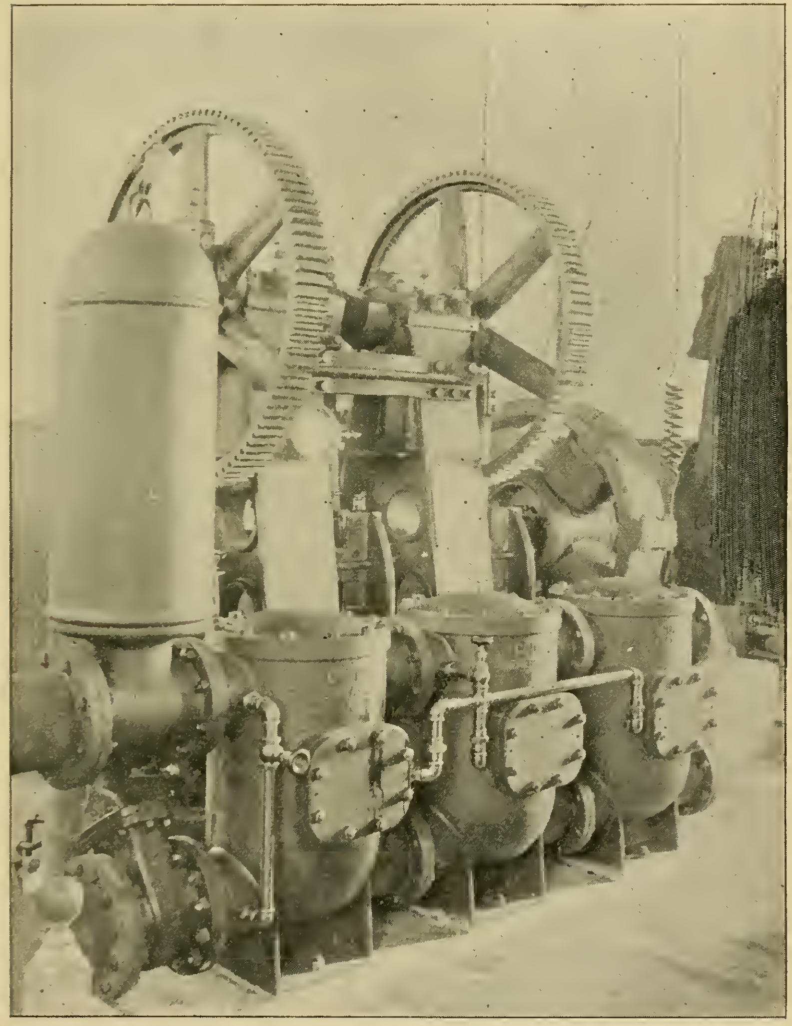


FIG. 7.—PUMP AND MOTORS, FRONT VIEW.

wearing parts can be readily taken up. The motors are coupled directly to the pinion shaft of the pumps and the speed of the motors is reduced by proportioning the pinions and gears in the ratio of one to five and

two-thirds. The gears are cut and the pinions are made of raw hide held by bronze shrouds. First-class workmanship was specified, and the Gould Company have strictly complied with the specifications and

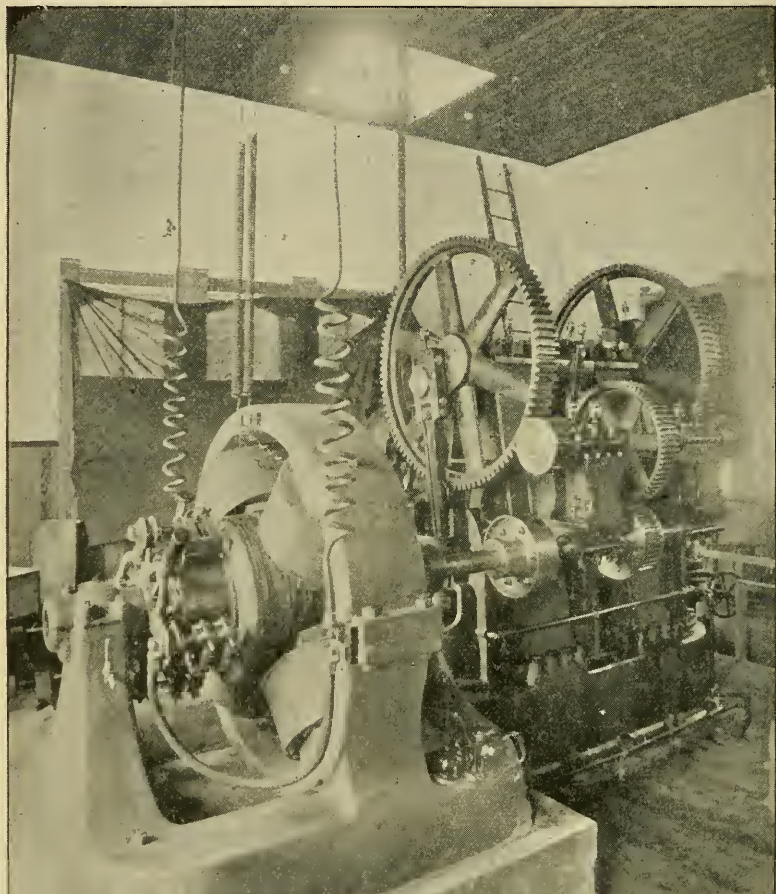


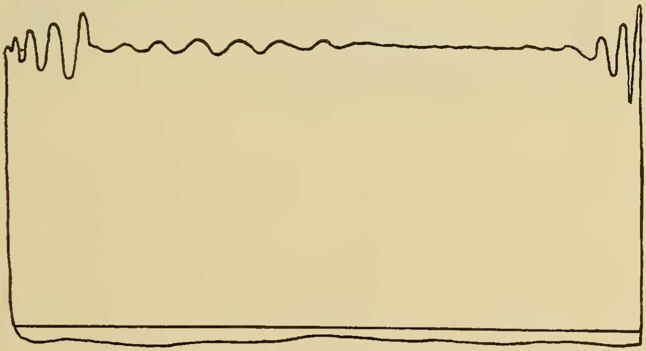
Fig. 8.—Pump and Motors, Rear View.

furnished a pair of pumps which, while solid and substantial in construction and free from vibration, are yet highly efficient. Both of the pumps were carefully tested.

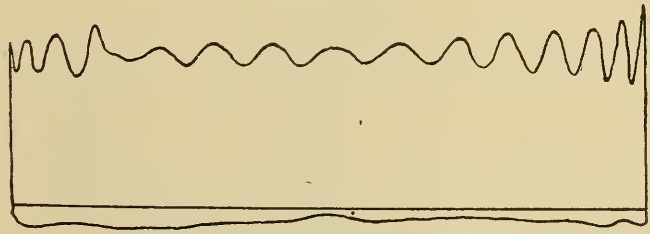
The test of the west pump was as follows:

TEST OF WEST TRIPLEX PUMP.

Time from	9.08	9.58	10.06	10.38	11.32	1.16
Time to	9.30	10.02	10.20	10.50	12.00	2.00
Amperes	27.3	130	156	206.5	215.75	243.3
Volts	217	195	193.4	195	192	186.8
Watts	8094	25350	30170	40255	41433	45455
Electric H. P. furnished	10.85	33.95	40.44	53.95	55.54	60.93
H. P. delivered by motor		29.13	36.14	49.1	50.84	56.60
Water pressure, lbs., No. load		66.5	84.5	125.5	126	129.5
Suction lift, lbs.		4	4	4	4	4
Total lift		70.5	88.5	129.5	130	133.5
Area plungers, square inch		78.54	78.54	78.54	78.54	78.54
Length of stroke, feet		1	1	1	1	1
Revolutions per minute	43.9	41.75	41.71	42.5	42.5	45.93
Effective H. P. delivered by pump, including slip		20.01	26.27	39.29	39.44	43.78
Combined efficiency of pump and motor		58.6	64.9	72.8	71.0	71.9
Efficiency of pump, including slip		68.7	72.6	80.2	77.5	77.3
Slip		2.1	2.1	2.1	2.1	2.1
Net efficiency of pump		66.6	70.5	78.1	75.4	75.2



60 pounds spring; 90 pounds pressure.



60 pounds spring; $47\frac{1}{2}$ pounds pressure.

FIG. 9.—PUMP CARDS.

The efficiency under the contract was to be 75 per cent. for the pumps under full load and 68 per cent. under half load. The former was exceeded in the test. The latter was not quite reached at 66½ pounds pressure. But as the pumps were new and the packing about the pistons was tighter than necessary it was evident from the work of the pump that it could easily reach the guaranteed efficiency. This was afterward exceeded on a further test.

The pumping plant is connected with the water mains by a 12 and 10-inch force main, intersecting the old system of mains at four points. Plans were made for an additional main between the pump-house and the water mains by another circuit when the growth of the city shall require, and for reinforcing the present system of 4-inch mains with 10, 8 and 6-inch pipe in such a manner that a reasonable fire service can be obtained.

In their contract with the city of De Kalb, the De Kalb Electrical Company assume the care of the pumping machinery and agree to furnish all oil and waste and all fuel needed to keep the engine house warm in winter. They also made the connection between the motors and their power-house, which was done by two circuits leaving the pump-house in different directions in order to provide against accident to the service line. They further agree to make all repairs on the machinery free of expense for labor, the city to furnish the material for the repairs. The General Electric Company have guaranteed that the repairs on the electrical machinery shall not exceed 2 per cent. per annum during the first five years.

Regarding the service to be furnished the De Kalb Electrical Company agree to maintain a minimum depth of 15 feet of water in the reservoir at all times and a minimum height of 55 feet of water in the standpipe with a daily average of at least 65 feet. They are to receive as compensation for pumping the water from the well into the standpipe 4 cents for each 1,000 gallons pumped. The average standpipe head pumped against is about 62½ pounds pressure per square inch. The De Kalb Electrical Company are also to furnish water for fires under any pressure required by the city not to exceed 125 pounds per square inch at the pumps, for which service no extra compensation is allowed. When fire pressure is desired the standpipe will be closed by a Dousman automatic pressure retaining valve, which is so arranged that by increasing the velocity of water into the standpipe the valve closes automatically and the pressure can then be raised as desired. When the pressure is again reduced the check valve opens and the standpipe is again brought into service. This valve also closes when the water in the standpipe reaches a certain elevation, in this way preventing overflow.

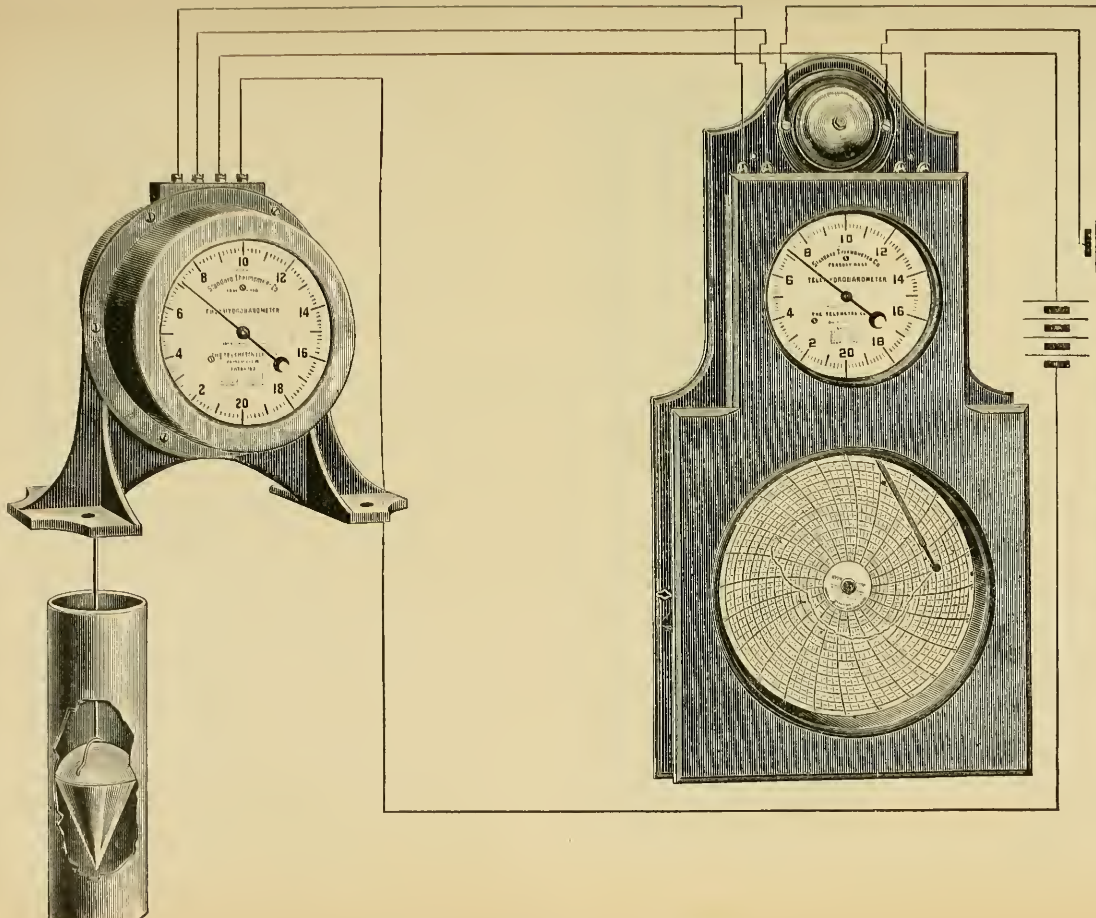


Fig. 11.—Tele-hydro-barometer.

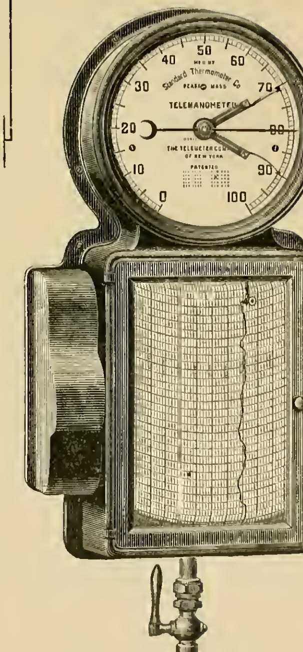


Fig. 10.
Recording Pressure Gauge.

The desired fire pressure is determined by setting the relief valve at the pump-house and when the pressure exceeds the desired amount the relief valve opens and the water passes back into the reservoir, thus preventing accidents by overstraining the mains. Accidents due to starting the pumps with the discharge valves closed are prevented by the use of fusible plugs at the power station. These plugs burn out before damage can be done to the motor, should the current become too strong.

The lack of available information concerning many points of importance in the design of the new work and the extension of the system, and the necessity of systematic records, became very obvious when investigating the De Kalb water works.

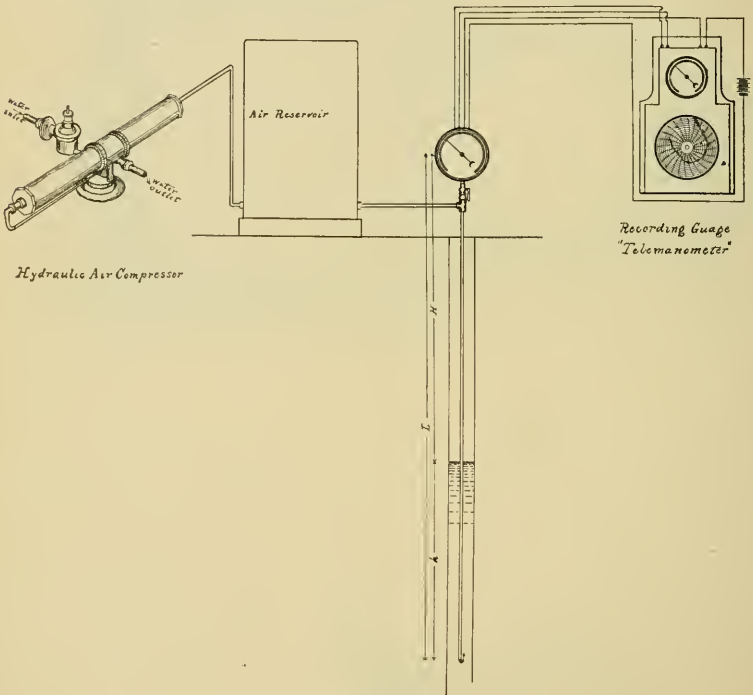


Fig. 12.—Deep Well Gauge.

The agreement with the De Kalb Electrical Company also rendered it important that systematic and automatic records should be kept in order that the manner of carrying out the agreement should be known beyond question. This was important for the protection of the company as well as for the city itself. For these reasons a number of recording devices were introduced into the system and made a feature of the works.

To measure the amount of water pumped, counters were attached to each pump. For the deep-well pump this furnishes, with the known capacity of the reservoir, a check on the slip of the deep-well pump valves. For measuring the water pumped into the mains, besides the pump counters, a 12-inch Venturi meter was purchased of the Builders' Iron Foundry of Providence, R. I. (see Fig. 13). This meter is provided with an automatic register which records the water pumped in cubic feet (see Fig. 14). The counters on the service pumps furnish a check on this meter. It was intended to secure a graphical record of the hourly, daily, weekly and monthly variation in the consumption of water, but, although the manufacturers were considering a recording device of this kind, they had not perfected the same, and were unable to furnish such a device.

To keep a record of the height of water in the standpipe and the pressure carried at all times, including fire pressures, a recording press-

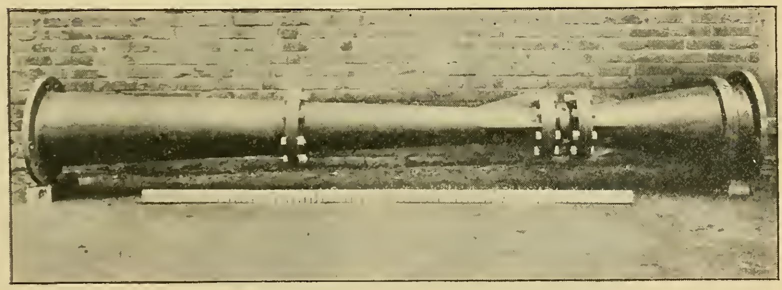


FIG. 13.—VENTURI METER.

ure gauge (see Fig. 10) was placed in the City Clerk's office, and attached to the main by a suitable connection. This pressure gauge was furnished by the Standard Thermometer Company, and includes both an ordinary dial gauge and a graphical recording apparatus. To keep a record of the height of water in the reservoir a gauge, called a tele-hydro-barometer, was purchased from the same company (see Fig. 11). The general principle of this gauge is easily understood from the illustration. The elevation of the float is shown on the dial at the reservoir, and is also shown both by dial and by a graphical record on the recording device which is also located in the office of the City Clerk.

Before drilling the last deep well at De Kalb, which is now used for the new public supply, an attempt was made to secure data concerning the various artesian wells which had been previously drilled in that city. No data on which reliance could be placed could be obtained. It is known by those who have paid attention to deep and artesian wells that

there is a change of level in the waters of these wells which has often a serious effect on their utility. In some cases this is caused by the sinking of new wells, or the abandonment of old ones. In others by the gradual filling up of the wells by sand, etc., or by the opening of the pores of the rock by solution. It is also believed that there is a seasonal variation in the flow of wells, and other variations due to barometric pressure. No extended series of observations have been made on these subjects, and had they been made at any one place they would still be inapplicable, except in a general way, to the locality under consideration.

One clause of the contract with the DeKalb Electrical Company provided that they should not be required, either at the present works or at any new works which should be built, to lift water with the deep-well pump more than 175 feet from below the surface. All of these considerations, together with the certainty of the necessity of the ultimate enlargement of the plant, rendered it desirable that detailed information be secured concerning the new artesian well.

The writer provided, in the specifications for deep-well pumping machinery, that a deep-well gauge, either on a plan proposed on drawings furnished, or on some other approved plan, should be provided. Mr. E. E. Johnson, M.E., Mem. Wes. Soc. Eng., offered the best suggestions for such a gauge. Mr. Johnson's suggestions were that by means of a small air compressor attached to the deep-well pump, air should be slowly forced through a small pipe running down the well to at least as low a point as the bottom of the pump cylinder. The pressure required to displace the water in this small pipe could then be measured by a pressure guage, and the length of the air pipe being known, the depth of water above the base of the pipe would be shown by the guage, which could be graduated, if desired, so that it would read directly in feet below the surface. The only objection to this was that no record could be kept when the deep-well pump was not running, and it was desirable to use some other motor beside the pump itself to operate the air compressor. Mr. L. B. Merriam, Mem. Wes. Soc. Eng., who superintended the construction of the plant as herein described, and whose efficient work was greatly appreciated, suggested that a Bishop & Babcock hydraulic air compressor be used for this purpose. This suggestion was also adopted. This compressor furnishes all the air necessary at a small expense for water, using about 500 gallons per day.

To make a permanent record of the well gauge readings, a telemanometer was purchased, the recording device of which is to be placed in the City Clerk's office (see Fig. 12). The recording pressure gauge and the deep-well gauge revolve once per day, and the cards have to be removed, dated and filed daily. The reservoir gauge revolves once in

seven days, as the variations are slight and the record for short times not as important.

From an economical standpoint the immediate saving in expense

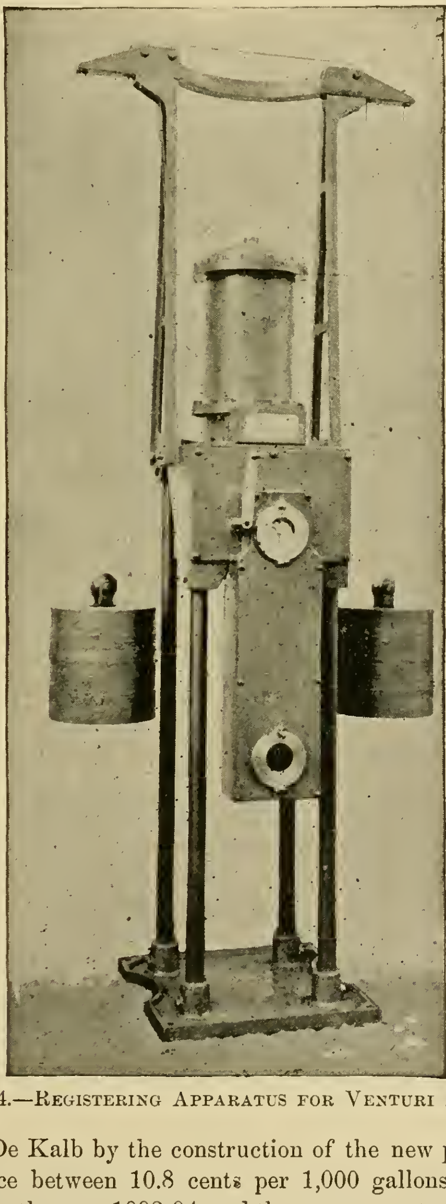


FIG. 14.—REGISTERING APPARATUS FOR VENTURI METER.

to the city of De Kalb by the construction of the new plant is obvious, as the difference between 10.8 cents per 1,000 gallons, the expense of pumping during the year 1893-94, and the present contract price of 4 cts. per 1000 gallons speaks for itself.

The economy of pumping in the way herein described, where large amounts of water are to be used and economical management is attainable, is, however, more than doubtful. This can be readily understood by tracing the loss of power through the system. Neglecting the matter of deep-well pumping, the loss in domestic pumping is as follows: There is first a loss of about 10 per cent. at the dynamo; an additional loss of 10 per cent. in the transmission of power from the dynamo to the motors; a loss of 16 per cent. through the motors and a loss of 32 per cent. in the pumps. This gives a net efficiency of the plant for domestic service from the power developed in the engine of only 46.27 per cent. The efficiency for fire service is, however, about 55.28 per cent., but fire service of course constitutes a very small amount of the pumping. With a steam engine equal in economy to that operated by the De Kalb Electrical Company, and the same class of pumps, but proportioned for the domestic work, the loss would be not more than 25 per cent.; the efficiency of the plant from the power developed by the engine in this case being 75 per cent. In this case a pump for fire purposes would need to be held in reserve.

The advantage the Electrical Company has over a municipal power plant is in the greater economy of the larger power plant and in the advantage to be derived from good business management as compared with the ordinary municipal management. The principal advantage is, however, that they can do the necessary pumping at such times as their other business is at a minimum, and they pay nothing extra for the services of engineer and fireman, and the incidental cost of operating the power plant. The proportional extra cost of coal is probably not as large as the proportional increase in power furnished; for the numerous losses incidental to the operation of a power plant must occur in any event and are not largely increased by the additional power developed.

The writer's estimate for pumping 200,000 gallons per day with a steam pumping plant, with good management, was, including all expenses, $5.71 per day, against the contract price of $8.00 per day for the same amount pumped. With a greater consumption, the difference would be greater; with a smaller consumption the difference would be less, and with a consumption of 150,000 gallons or less the difference would be in favor of the electrical plant. The average consumption of water for the last three months has been but little over 100,000 gallons per day. There will doubtless be a rapid gain in consumers, however, with efficient service and a constant supply.

The value of any system and method is relative only. A system which is economical under one set of conditions, may be the reverse where the conditions radically differ. It is only by practical illustrations that the economy of any particular system can be fully developed

and thoroughly understood. As a practical illustration of the application of electricity to the municipal water-works service, it is believed that the De Kalb plant will not be without interest.

DISCUSSION.

After reading the paper, Mr. Mead exhibited a number of illustrations by means of stereopticon views, with explanations, as follows:

The map and sections (Fig. 1) illustrates the geological conditions in the Upper Mississippi Valley and the relation of the water-bearing strata. The St. Peter sandstone is the source of supply for the city of De Kalb as well as for a number of other cities, shown on the map. There are also a large number of deep and artesian wells in Chicago that are drilled into both the St. Peter and Potsdam sandstones. The more shallow wells are into the St. Peter sandstone and the deeper wells reach the Potsdam sandstone. The sections at the bottom of the map show the relative vertical positions of the St. Peter and Potsdam sandstone. Lying just above the Potsdam sandstone is about 150 feet of the lower magnesian limestone, which furnishes an impervious cover and to a considerable extent confines the water in the pervious sandstone. On top of the magnesian limestone lies the St. Peter sandstone, which is throughout Northern Illinois about two hundred feet thick. Both of these deposits, the Potsdam and St. Peter, are sandstones which allow the free passage of water. The water probably also very largely passes through fissures in the rock as well as through the rock material itself.

The north and south section is on a line passing near the position of De Kalb. The water from the St. Peter sandstone at De Kalb is found to be higher than the water from the St. Peter at Rockford, which is unusual, as De Kalb is considerably further south, and the hydraulic grade of these waters usually descends toward the south. This fact would show that the water at De Kalb really comes from a point considerably further north than that at Rockford, and at a consequent greater altitude. There is an out-crop of the St. Peter sandstone at Dixon, Ill., along the Rock River, and also at Ottawa, Ill., along the Fox River. Ottawa is built practically on the St. Peter sandstone.

Fig. 2 shows the relative location of various features of the De Kalb water-works system. The Kishwaukee River is just to the west of the pump-house and reservoir. It is dry most all the season. The main reason for locating the plant at this point was in order to get a switch for the delivery of coal, as it was originally intended to erect a steam plant. This location is also one of the lowest points in the city It was originally expected that we should be able to reach the water without the use of a deep-well pump, by sinking a shaft, but the water did not rise as high as was expected, and this idea had to be abandoned.

Ths reservoir, which is located just west of the pump-house, will hold a half million gallons of water.

The electric power plant is shown at the east end of the map. One line of wire follows the railroad down to the pump-house; the other follows the streets, so that they have two separate lines in case of accident. The point where the standpipe and the old pump-house are located is about the highest point in town.

A 12-inch main was laid to join the old pipe system. A 10-inch pipe connects the 12-inch with the system at several points. There is also a 10-inch pipe running from the old pump-house to the standpipe, but the pipe joining the two 10-inch pipes is at present 6 inches. This will be changed as soon as the finances of the city will permit.

Fig. 3 gives a general view of the interior arrangement of pump-house, and the location of the well, the deep-well pump, the service pumps and the motors. The water is raised by the deep-well pump and forced through a 6-inch pipe into the reservoir. The valves are so arranged that it is possible to pump into the mains with the deep-well pump if it becomes necessary, or to pump directly into the suction of the service pumps, if for any reason it becomes necessary to fix the reservoir. The service pumps, of a capacity of 500 gallons per minute each, are located as shown in the figure. The Venturi meter is also located in the pump-house at the point shown. No test was made of the Venturi meter, but allowing for the slip of the pumps, the meter and the pump counters were found to agree very closely. The pumps are positive in motion, and so that the counter measured exactly the amount of water pumped, plus the slip of the valves. The Venturi register is located just above the meter in the pump-room, and records the amount of water in cubic feet.

In Figs. 4 and 5 the deep well cylinder and valve that are used at De Kalb are shown. The illustration shows the valve both closed and open, and shows very plainly its action. When open, the valve gives almost a straight water way and closes very closely, giving very little slip. The double-acting pump cylinder is also shown in the cuts. The rod of the upper valve is hollow, and the rod of the lower valve passes through it. These rods are actuated by a pump-head in which the eccentrics are placed opposite each other, or at an angle of 180 degrees, so that when one rod is going down the other is raising. The rods are arranged to balance each other in weight, so that there is less loss in the action of the pump than in a single-acting pump. See Fig. 6.

Fig. 7 gives a front view of one of the service pumps and motors. Fig. 8 gives a rear view of the same. Fig. 8 shows the motor nearest the observer, and of course the size of the motor appears much larger relatively than it really is. The direct coupling between the motor and

pump is quite clearly shown in the illustration. The pinions that run the main gear, as well as the pinion on the motor shaft, are raw-hide; the others are cut-gears.

Fig. 9 shows two pump cards taken from one of the cylinders on one of the service pumps. One is taken while the pump was working against 90 pounds pressure; the other while the pump was working against about 47½ pounds pressure. The horizontal lines in the illustrations are the atmospheric lines.

Fig. 10 is a view of the recording pressure gauge, which is attached directly to the main and is located in the City Clerk's office. The card is removed and replaced every day, and in this way a record is kept of the pressure at all times, including, of course, during fires. The height of water in the standpipe is also shown by this gauge. This gauge protects both the city and the electric company, for with its evidence no unjust claim can be sustained as to what pressure they had or did not have at any particular time.

Fig. 11 illustrates the tele-hydro-barometer. This, as well as the recording pressure gauge, was made by the Standard Thermometer Company. The float is placed in the reservoir and marks the depth of the water. This depth is shown on the gauge above the float and also on the recording device, which is located in the office of the City Clerk. This record will show whether the Electrical Company are complying fully with their contract in keeping a sufficient amount of water in the reservoir.

Fig. 12 is a diagram of the deep-well gauge. On the right is shown a Bishop & Babcock hydraulic air compressor. The air passes from this into the air reservoir and thence into the small pipe, which runs into the deep well. Just enough air is furnished to keep it bubbling slightly from the bottom of the pipe, and the amount that the water is depressed is shown by the pressure on the gauge at the top of the pipe. From this pressure the distance from the floor to the water surface can be calculated by the formulæ. $H = L - h$, where L equals the distance from the center of gauge to bottom of air pipe, h equals gauge reading in feet, and H equals distance from center of gauge to the surface of the water. The fluctuations in the surface elevation of the water can in this way be ascertained. To record the fluctuations, a tele-manometer recording gauge is used, which will also be placed in the City Clerk's office with the other gauges. This gauge will give a record of the well variations at all times during the day and night, and it is hoped that in this way some valuable information concerning the seasonal and other variations in the water of artesian wells can be ascertained. This, it is believed, will be of the greatest advantage if at any time it is desired to extend the system.

Figs. 13 and 14 give views of the Venturi meter and register.

THE PRESIDENT.—The 22 per cent. difference in the efficiency between motors and steam plants suggested is a little startling. The question would naturally arise, unless electric motors are somewhat of a plaything, why the city of De Kalb, in trying to pump water, did not use the steam plant. It certainly would cost less. Am I right in that conclusion?

MR. MEAD.—The question of ultimate economy is not one of efficiency alone, but of attendance as well. The De Kalb Electrical Company need no extra men on account of the extra power furnished the city for pumping, but are doing the work with the same force with which they ran their plant before contracting with the city. If a steam plant were used by the city for pumping, attendance would have to be provided, and this cost would have to be added to the cost of operating the plant. Besides this, the type and the size of the engine used would make considerable difference in cost of operation, while it would not make any difference in the efficiency of the two types of pumping plants mentioned. I have based my estimate of efficiency on the power generated by the engine, and the type of engine used would therefore not modify my estimate, while it would modify the cost of pumping to a large extent. Different types and sizes of engines use all the way from 12 pounds of steam per horse-power per hour up to perhaps as high as 100 pounds of steam per horse-power per hour, and the use of an inefficient engine and the extra cost of attendance might make the more efficient pumping plant much more expensive to operate.

THE PRESIDENT.—Well, to follow up the thought: was there anything preventing the placing of the power plant of the Electric Company adjacent to the pumping plant, so that they might transfer the power of the large engine direct to the pumps?

MR. MEAD.—No and yes. The original idea was to build a steam plant. It was expected at the time when the well was first drilled that a steam pumping plant, to be operated by the city itself, would be used. The well was drilled, therefore, in its present location on account of its being the lowest point in the city, and also being adjacent to the railroad. For this reason this position of the plant was fixed. Afterwards the Electrical Company made a proposition to the city to operate the plant by electricity, which was finally accepted by the City Council. My estimates were that, on 200,000 gallons of water per day, which amount we expect the city of De Kalb will use, the cost will be, including cost of attendance, about $5.75 per day. Under the contract with the Electrical Company, the cost of pumping 200,000 gallons per day will be about $8 per day. The difference in the cost per diem between the two methods of pumping will grow much larger as the amount of

water increases. If, on the other hand, as is just now the case, the amount of water pumped is 100,000 gallons per day or less, the city could not have pumped this amount as cheaply per 1,000 gallons with the proposed steam plant as the De Kalb Electric Company will pump it for them with the present electrical plant.

THE PRESIDENT.—The question in my mind was about this Electrical Power Company.

MR. MEAD.—To explain further, the city was to construct their own pumping plant The De Kalb Electrical Company desired to do the work of pumping. Now, they could have done it cheaper, I have no doubt, if they could have coupled their engine directly to the pumps. This, however, would have been impossible even if the well had been adjacent to the power station. The De Kalb Electrical Company are furnishing power and light. They are obliged to run their plant in any event, and although the efficiency of the arrangement is low, the cost of operating the pumps is very small, as nothing extra is paid by them for attendance. They are, in fact, utilizing what may almost be considered waste power.

MR. JOHNSON.—Coming in late, I missed part of Mr. Mead's paper. I should like to ask the gentleman if he stated the combined efficiency of the plant and the efficiency of both the motors and pumps?

MR. MEAD.—I gave the combined efficiency of the plant as about 47 per cent.

MR. JOHNSON.—Do I understand that that is the efficiency of the electrical motor and pump combined?

MR. MEAD.—That is the efficiency of the plant from the De Kalb Electrical Company's engine clear through the pump. It is the power actually utilized after deducting the loss in generating the electrical current, the loss in transmitting it from the dynamo to the motor, the loss in conducting it through the motor and changing it into power, and the loss in the pump itself. The loss in the pump, as I have explained in the paper, is greater on domestic service than it would be on the fire service. The pump is designed for fire service. With the same pump designed for domestic service, that is, a pump of the same general class, but designed for 60 pounds instead of for 125 pounds service, we should probably get an efficiency of 75 per cent. in a test. These pumps showed an efficiency in one test, on a full load, of 78 per cent. The motor under half load showed an efficiency of 84 per cent., then under full load it showed an efficiency of 91. I was simply stating the fact that under domestic pressure the efficiency of the plant from the engine through the pumps was about 47 per cent. While with the engines at the pump-house, and with the same pump attached directly to it, an efficiency of from 70 to 75 per cent. of the

power of the engine could be obtained. The Electric Company simply have the advantage of having a larger steam plant, which is probably of a better type than the city would purchase, and they have the further advantage that their plant is managed on business principles. They have the disadvantage of the difference in efficiency.

MR. JOHNSON.—May I ask further if you have data for the efficiency of the engine and the generator, so that you could get the presumed loss of the generator?

MR. MEAD.—The loss in generating the electrical current was estimated, and was not from any experiments or tests that I made myself. I think the Electrical Company have determined that they can obtain 90 per cent. efficiency from their generators.

I made no test of the deep-well pump, as the deep-well pump at present is a temporary one. I believe, however, Mr. Merriam has made some preliminary tests on the present plant and I think he can give us some data.

MR. MERRIAM.—I do not believe I can add very much to what Mr. Mead has said, with the exception that we did make an approximate test to-day on the efficency of the deep-well pump. We found the efficiency of the pump itself to be about 60 per cent. I think this is very high for the work it is doing, that is, it was lifting about 200 gallons of water a minute a height of 110 feet. By previous experiments we know there was very little slip in the pump. We ascertained the slip by taking careful measurements of the reservoir and compared the water pumped with the number of strokes of the pump. I have seen several experiments with the ordinary steam head on deep-well pumps, and I found that we only obtained about 45 to perhaps an extreme of 55 per cent. with the very best of designs.

THE PRESIDENT.—On the question of the deep-well pump I have had a little experience, and I would like to make an inquiry as to what success is obtained in connection with these rods, one running inside the other. How often they have failed, if at all?

MR. MEAD.—I cannot speak from experience at De Kalb. The pump at that place has only been in use for a few months. At Monmouth, Ill., one of the direct double-acting steam-heads has been in use for something over three years, and the Superintendent of Water Works tells me that they have had very little trouble. I don't think that they have had a breakage once in six months. At De Kalb there have been one or two breakages, which I think are due perhaps to the fact that the well is not perfectly straight.

THE PRESIDENT.—Will you tell us what size these rods are?

MR. MERRIAM.—The outside rods are an inch and a half in inside diameter, I think, and the inside rod is an inch and an eighth in diameter.

Mr. Mead.—The inside rod is a solid steel rod. The outside rod is inch and a half steel pipe. The breakage always occurs in the outside rod where the thread is cut, which is of course the weakest point. In the new design for the rods which I have proposed, the outside rods are to be made of wrought-iron pipe, upset at the ends so that the outside rod will be as strong at the coupling as at any other point.

The President.—I would like to know what the city of De Kalb spent in getting this plant in working order, and I would like to know further the saving to the city in the amount of water they are pumping?

Mr. Mead.—The total cost of the plant was about as follows:

Ground for pump-house and reservoir	$ 425 00
Cost of well	2,100 00
Reservoir	6,700 00
Pump-house	2,550 00
Pumps and motors	7,000 00
Venturi meter	600 00
Water mains laid	6,500 00
Miscellaneous costs, including engineering and supervision	2,000 00
Total	$27,875 00

The cost of pumping into the standpipe was about 11 cents a thousand gallons before the new works were constructed. The cost of pumping under the contract is 4 cents a thousand gallons. Concerning the new arrangement, the City Clerk in his annual report writes as follows:

"With this report I have prepared the table giving the daily average of each of the nine months (under the old system) of the number of gallons of water pumped, also daily cost of engineer, coal, supplies and total cost per day. Also daily revenue from water tax collections, and the excess of costs over and above the water revenue. To save time I will give you the daily estimate for the whole term of nine months:

No. gallons water pumped	87,500	
Cost of engineer		$4 21
Cost of coal		7 26
Cost of supplies		1 06
Total cost per day		$12 53
Daily revenue from water tax		7 93
Cost over and above revenue per day		$4 60

or $1,679 per year.

"Under the new system of water works for the months of February, March and April, the daily average of water pumped is 100,481 gallons;

cost per day, $4.02; the daily revenue from water-tax is $7.93, bringing in a gain to the city over and above expenses of $3.91 per day, or $1,427.15 per year.

"This present revenue, with interest, will be sufficient to pay off all of our bonded indebtedness by the year 1909."

From this it will be seen that for the nine months for which this report (which has just been received) is made out, the cost of pumping has been over 14 cents per thousand gallons pumped.

Mr. Merriam.—It seems that this matter of small municipal pump plants is one that should be of considerable interest to all of us. These plants have heretofore been put in about in this way: A contract is made, and a standpipe is put up; and a pump, a double-acting duplex, or some ordinary type, is put in. No particular regard has been paid to the efficiency of the outfit because it is small, and it is thought to be too small to pay any attention to its efficiency. It is thought it is all right if it is a pump and pumps water. Now, it seems to me that Mr. Mead has attacked this problem in the right way. Although the plant is a small one, he has paid considerable attention to the most economical and efficient arrangement possible under the circumstances. And I think this idea is worthy of being followed out in the design and construction of all pumping plants, even if they are small.

I want to make one further remark about this efficiency of the engineering work in this particular case. The city of De Kalb had spent, before Mr. Mead was called there, about $65,000 in a water-works plant. The mains were very largely of 4-inch pipe. They had, however, a very good standpipe, and they had a pump and three deep wells. The city paid out $3,700 per annum for the last year's pumping, and they received about $2,700. Now it appears, from the present prospect, that it will cost the city about $1,400 or $1,500 to do their pumping. Their income will be the same, $2,700. The entire expenditure for the new works is about $30,000. The interest on this entire expenditure will be saved, and in addition to that there will be a small profit inside of the receipts, as against $2,000 loss on the previously existing pumping plant.

Now, I think, as I said before, that this plant has been attacked from the right point of view. There has been an attempt to obtain the very best results, and, I think, there are a good many of these small towns—five, six, or seven thousand inhabitants—that are worthy of our best thought in that manner. I think the more we discuss these small plants the better we will be off, because I think we will learn actually more from the discussion of small plants than of the large plants that only a few of us at best will ever get a chance to design, because there are too few of them that are being built.

I wish to say further concerning the De Kalb plant that if the well were moved to the power-plant, and it was still run by the Electric Company, it would have to be run through shafting, that is, it could not be attached direct to the engine. If it were attached to the shaft they could hardly get along with a less loss than at present, for they would have three pumps attached to the shaft, which would be a long, heavy shaft, or they would have a shaft and two or three counter shafts. Now, I do not think that there would be any gain in this method ; I think there would be at least 10 per cent. loss in that shaft, so that the only remaining loss we have is the transmission of the power. If the pumps were attached to independent engines, each of which was intended for pumping alone, there would be two 50 horse-power engines and one 25 horse-power engine, and it would be pretty hard to obtain anything near the efficiency that the De Kalb Electric Company obtains with the compound engine of 125 horse-power. I am very much in doubt with regard to the possibility of running the plant with any greater efficiency, even assuming the 200,000 gallons per day, especially by a city. You know the appointees of a city are generally put there more or less by politics or favoritism, and such help is, as a rule, incompetent.

When the old De Kalb pumping plant was in use they had a steam-head on their deep-well pump. I put two gauges on the pump-head and I found out that, on the up-stroke, they actually had a ten-pound cushion against their work ; well, it wouldn't take very many ten-pound cushions to do away with the entire efficiency.

The President.—I would like to ask in connection with the steam-head on deep-well pump working against a certain per cent. of back pressure, if it was making half the stroke it was presumed to.

Mr. Merriam.—It was making about a three-quarter stroke.

The President.—Well, it was doing very well.

Mr. Mead.—One point concerning the efficiency of this plant it would be well to bear in mind. The De Kalb Electric Company are using the water tube boilers, a good grade of engine, and it is probable that the economy of their steam plant is very fair, and that the steam plant is run under very fair conditions.

Now if, for instance, their engines are run with 20 pounds of steam per horse-power per hour, and if the city should have a steam plant, and should generate steam as economically as the De Kalb Electric Company, but should use a lower grade engine which would take 40 pounds of steam per horse-power per hour ; under these conditions you will see that 20 pounds of steam in the Electrical Company's engine would practically do the same work, with even a loss of 50 per cent. in efficiency, at the same expense for coal as in the case of the city plant of lower

grade; all of which is due to a difference in the class of the machinery used.

I believed in the first place, and still believe, that a steam plant would give better results for the city of De Kalb than can be obtained by the plant as built, provided they could and would obtain a reasonably good steam engineer to manage the plant. Their experience in the past would not perhaps warrant one in drawing such conclusions, but it is a fact that, with reasonably good management and reasonable economy in the machinery, better results than are now being obtained might be expected. I made a careful estimate and calculated the cost of the 200,000 gallons of water a day at about $5.71, as against the $8 actual cost at present. This estimate was based on facts as we find them in other places, and I think this could be easily reached by reasonably good economy in the plant proposed. However, this plan was not adopted, but the city decided to try the electrical plant, which certainly largely reduced the previous cost of pumping, and is also at present more economical than the steam plant would be. For the city is not at present using more than 100,000 gallons per day. In the long run, however, and long before the contract with the Electrical Company expires, I believe a plant operated by the city would prove far more advantageous to the city of De Kalb.

Concerning the pumping plants of the smaller cities and towns I wish to say one word further. In the larger plants great attention is paid to having engines which will give a high efficiency. It has appeared to me that in the small plants the question of efficiency is also a very important point. The original cost and the running expense of these small plants are usually higher per capita than in the larger cities. The same attention to economy therefore should be paid to the smaller plants as to the larger ones, at least as far as possible. This is not ordinarily done in selecting small pumping machinery. Neither do the manufacturers seem to give it any attention. The idea seems to be considered by the manufacturers not of importance enough to give it a moment's thought. The reason for this is of course obvious. There is not enough money in the small machinery to pay for the extra work, or for the designing of the higher grade machinery. Neither is the designing engineer paid enough ordinarily to warrant him in giving great attention to securing high-grade machinery, and as there has been no demand for this class of machinery there is therefore no supply, and will not be until the engineers and the public require it. But is it not equally as essential in a small way? Is it not proportionately as essential to have economically designed machines in the small works as in the larger plants?

Mr. Cooley.—It occurs to me that, as an offset to a separate en-

gine, you could put on a separate condenser that will heat the water in the well about 4 or 5 degrees.

A Member.—That same idea of temperature in the water had occurred to me when Mr. Mead was speaking of the deep-well gauge. I think the difference in the temperature of the water would make a difference in the reading of the gauge. I did not hear anybody speak about measuring the temperature of the water.

Mr. Mead.—The water in artesian wells is about uniform throughout the year. It may vary a few degrees perhaps, but as it is coming from 800 feet below the surface it preserves quite a uniform temperature. It is comparatively warm in winter and cold in summer. Most of the wells through Northern Illinois run perhaps from about 54 degrees to, in some extreme cases, as high as 60; about 54 to 55, I think, is the average of the most of the artesian wells. Variations in temperature of an individual well would be very small, and would therefore make little difference with the deep-well gauge.

A Member.—In connection with the temperature of the artesian well water, I would mention one point, and the experience may be somewhat useful to you, gentlemen. At Waukegan, there is an intake pipe running out into Lake Michigan. They had trouble with anchor ice, and to get rid of the anchor ice they turned the water from an artesian well into their intake pipe and flushed the anchor ice out. That part of it was a success. But the difference in temperature of the water caused an expansion of the pipes, so that they separated at the joints and they had to connect them up.

Mr. Ward.—Speaking of the pressure in artesian wells, I will say that in Marseilles we have something like 200 wells drawing all from the St. Peter's sandstone, and the water rises to the surface and flows at the surface. We have noticed there that the height decreases at the rate of from 4 to 5 inches a year. There is a regular decrease apparently in the height. There is one well there that, when I first drilled it, about 1884 or 1885, flowed about 3 or 4 feet above the surface. This is on rather high ground, and when the head was lowest, so that it began to flow merely to the surface, I noticed that there were times in which it would not flow at all, while at other times it would flow quite remarkably; sometimes it would cease entirely. The St. Peter's sandstone in that region comes to the surface at Ottawa. They use it to manufacture glass there. It outcrops along the Vermillion River and up the Fox River, and the dip is about 11½ feet per mile to north and east, so that we have to go down at some places 108 or 109 feet to reach it. The water evidently comes from Wisconsin, near Janesville. I think that at Marseilles, and along near Ottawa and just below Ottawa, and along the Fox River, there are large

springs of this same water that rush out from the rock. Some of these springs, like the one up near Dayton, just north of Ottawa, are very large. This one is probably over six feet wide and perhaps four to five inches deep, a constant stream running into the Fox River. There is another one something like that just below.

Mr. Roney.—I am informed that Mr. Mead has made a thorough and exhaustive test of a very interesting gasoline engine pumping plant, which he built at Dundee, Ill. I hope that Mr. Mead will favor us with a paper describing that plant and his very extended tests of it.

The President.—That is a suggestion that I endorse with all my heart. I think it might be well that these gentlemen, who have been raising critical questions concerning the question of efficiency of the De Kalb water works, express themselves emphatically that they do not see any bad business policy in getting water pumped for 4 cents a thousand gallons that has previously cost the city of De Kalb 11 cents.

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STOPPING A TROUBLESOME SLIDE AT A SUMMIT TUNNEL.

BY JOHN D. ISAACS, MEMBER OF THE TECHNICAL SOCIETY OF THE PACIFIC COAST.

[Read before the Society, April 5, 1895.*]

INTRODUCTORY.

PROBABLY no section of California within easy reach of San Francisco presents greater attractions than that portion of the Santa Cruz Mountains lying contiguous to the Santa Cruz Division of the Southern Pacific Railroad (commonly called the Narrow Gauge).

Leaving the picturesque town of Los Gatos, the southbound train ascends the wild and beautiful cañon of Los Gatos Creek, crosses a double summit and by easy grades descends into the fertile Santa Cruz region. In the short time of two hours the traveler passes from the wheat-fields of Santa Clara Valley, through the orchards and vineyards of the foothills, into forests of gigantic redwoods and wild mountain scenery, thence to park-like glades and lawns stretching to the yellow sands and blue waters of Monterey Bay.

There are on this line two summit tunnels, the first or most northerly of which is just at Wright's Station, and is known as Wright's Tunnel. It is 1.16 miles long, and for some two hundred feet from the northern end is driven through a clay stratum resting upon an inclined

* Manuscript received September 2, 1895.—*Secretary, Ass'n of Eng. Socs.*

rock bed which pitches northward towards Los Gatos Creek. The maintenance of this tunnel has always given trouble during the heavy winter storms for which this immediate section of country is remarkable, but no serious impediment to traffic occurred until the winter of 1892–3.

At this place, a tributary to Los Gatos Creek, which flows nearly due east, is joined by a side creek flowing north. Both creeks are nearly dry in summer, but become torrents in stormy weather. The railroad track crossed the side creek just at the mouth of the tunnel and a few feet away from its junction with the north creek.

In the heavy storms of 1892–3, the two creeks cut through the clay bed to the rock below, and the whole hillside for some three hundred

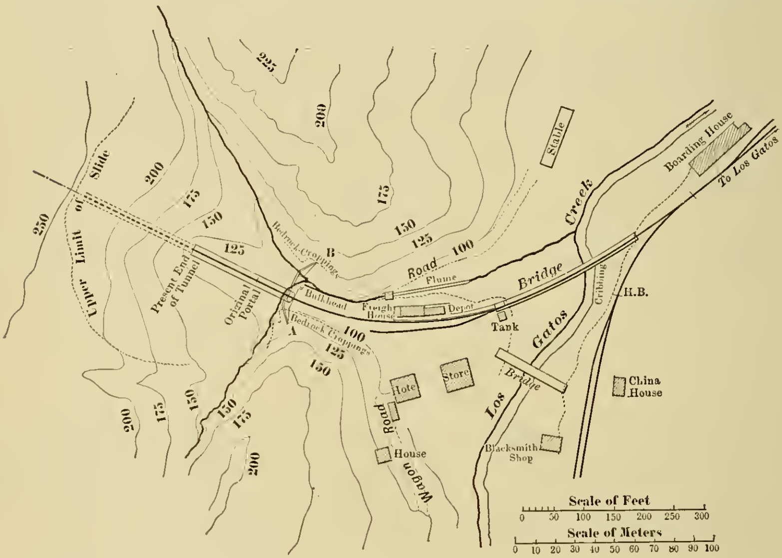

Fig. 1.

feet back slid forward towards Wright's Station, filling the narrow throat between the points of rock "A" and "B" on the accompanying map. The entire mass seemed to be afloat on a film of water between the clay and bedrock. The first two hundred feet of tunnel was crushed in and taken with the slide, and traffic on the road was stopped.

Attempts were made to reconstruct the end of the tunnel and portal with heavy timber and iron, but these proved failures. Not until the storms ceased, and a through cut was made, could traffic be resumed. As soon as dry weather set in, all was well; but it was evident that before the next winter one of the following courses of action must be taken:

(1) Do nothing, and abandon the road until spring.

(2) Hydraulic the slide out. As the condition of the bed beyond the slide was unknown, and as an inspection showed the ground to be seriously cracked for a considerable distance beyond the slide, it might prove to be a very serious undertaking, besides interfering greatly with the water supply of the town below, derived from the Los Gatos Creek.

(3) Re-establish and maintain the toe of the slide by raising the beds of the two creeks and by constructing a concrete masonry retaining-wall or dam from the rock points "A" and "B," pierced by a tunnel.

This last proposition, which originated in a discussion between Mr.

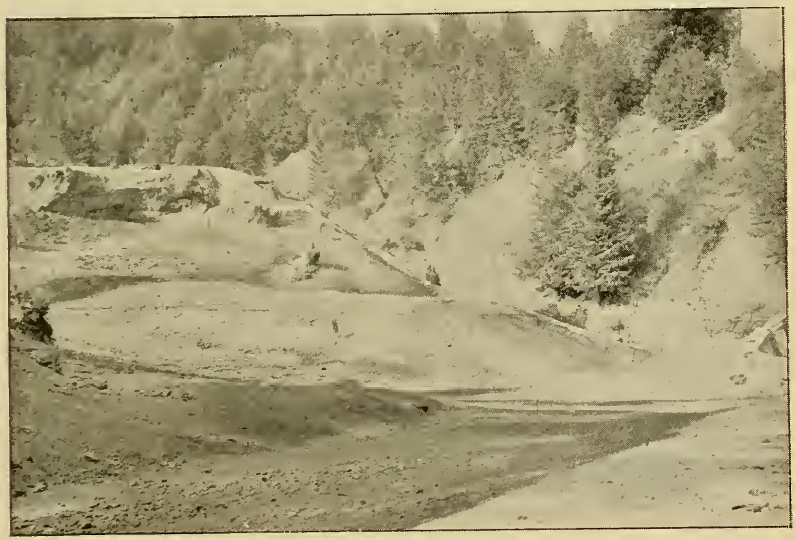

FIG. 2.

W. S. Palmer, Resident Engineer of the Santa Cruz Division, and our Vice-President, Mr. W. G. Curtis, was carried out, with highly gratifying results. A concrete retaining-wall was built, as shown on the accompanying drawings, pierced by a tunnel. The beds of the creeks were filled, re-establishing the toe of the slide, and the side creek from the south carried behind the wall over the top of the tunnel and made to join Los Gatos Creek just at a spillway in the westerly side of the retaining-wall, through which the combined streams now discharge.

The retaining-wall is about twenty-eight feet high from base of rail, fourteen feet thick at bottom and two feet thick at top. It is of the outline and form shown on plans herewith. The tunnel is oval in shape, and of varying thickness, as shown.

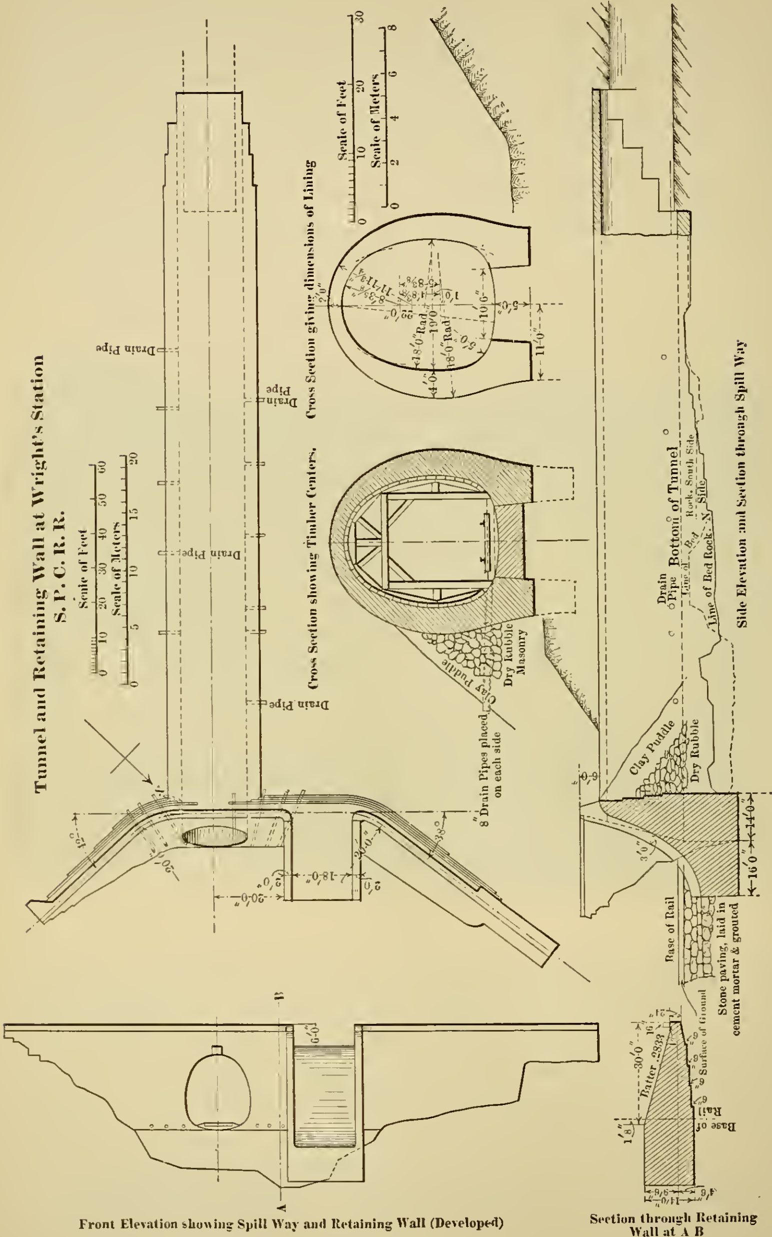
Tunnel and Retaining Wall at Wright's Station
S. P. C. R. R.
Scale of Feet
Scale of Meters
Drain Pipe
Cross Section showing Timber Centers.
Cross Section giving dimensions of Lining
Dry Rubble Masonry
Clay Puddle
8 Drain Pipes placed on each side
Bottom of Tunnel
Line of Bed Rock, South Side
Line of Bed Rock, N. Side
Side Elevation and Section through Spill Way
Dry Rubble
Base of Rail
Stone paving, laid in cement mortar & grouted
Surface of Ground
Batter .2833
Front Elevation showing Spill Way and Retaining Wall (Developed)
Section through Retaining Wall at A B

FIG. 3.

As it was desirable to avoid hydrostatic pressure on the retaining-wall, it was backed by dry rubble masonry, which was covered with clay puddle, well rammed, and separate drains were run from the rubble and from the slide behind it through the retaining-wall. The same arrangement was followed with the masonry tunnel.

As the tunnel cut through the slide, it had to be arranged to transmit the thrust of the slide from south to north. The sides of the barrel were, therefore, carried down to bedrock, and a key-piece put in under the track, as shown. The earth was well tamped and rammed on both sides of the barrel, and the top of the tunnel was loaded with earth from

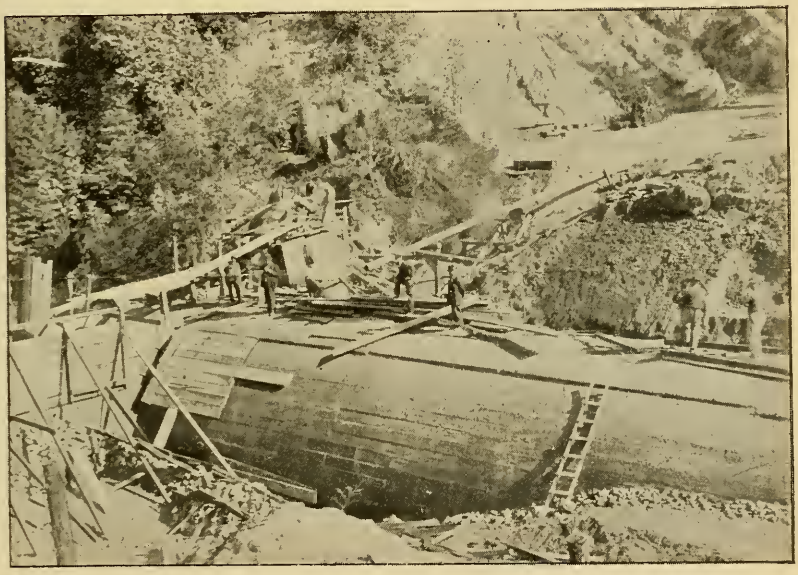

FIG. 4.

fifteen feet deep forty-two feet back from the retaining-wall, to twenty-five feet deep at its further end. In effect, the barrel was made part of the slide, and the slide provided with a toe.

MASONRY.—The entire work is a concrete monolith. All the concrete is mixed in the following proportion, by volume:

One part Portland cement,
Two parts sand,
Three parts gravel,
Four parts broken rock passing through a two-inch ring.

But all that portion below the base of rail, except the key-piece under the track, has placed in it large pieces of rock varying from one-quarter to one cubic yard, as follows: a layer of concrete six inches thick, hav-

ing been first laid, and while yet soft, large rocks were placed upon it, with their best bed down, the rocks usually standing on one of their ends, leaving a clear space of about eighteen inches between them, into which the concrete was afterwards rammed until the spaces were filled. Whenever there was room enough, smaller stones were thrown in and rammed with the filling, but care was always taken to surround all rock with concrete. It was thought by placing the large stones smaller side down they would bed themselves better in the soft concrete.

One tier or course having been thus built, the same method was pursued until the height of base of rail was obtained; above that, the same concrete mixture was used minus the large stones.

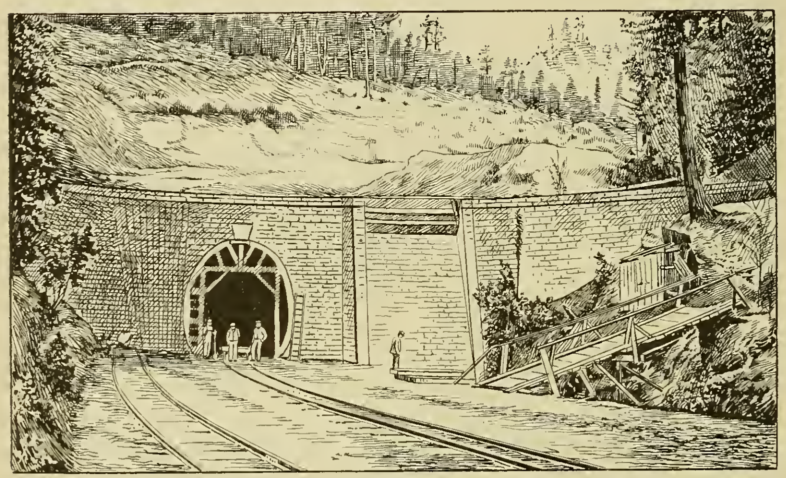

FIG. 5.*

The rock was a strong, heavy blue trap, obtained from the side of the road about three-quarters of a mile below the tunnel.

Sand and gravel were found mixed in nearly the proper proportion in a gravel bed just south of Campbell's, about ten miles north of the tunnel. Into this a series of spur-tracks were run, and the mixed sand and gravel loaded directly from the bank to the cars. A portion of this sand and gravel was screened and kept on hand separately, and additions of sand or gravel made as necessary.

MIXING.—Advantage was taken of an existing sidetrack put in when the cut was first opened, some thirty feet south of the main line and four feet above same, and the space between the two tracks

* The wall is of concrete, as stated in the text, not of masonry, as shown in the cut.—*Secretary, Ass'n of Eng. Socs.*

filled in with a mixing platform having its planking lengthwise. The top of this platform was level with the top of the cars on the siding and the planks over the proposed foundation left loose. Beyond the siding and further south the ground was benched at intervals level with the top of cars, and on these benches the cement was stored, making in effect, with the tops of the empty flats, a platform about forty feet wide. A train of cars loaded with rock was run on the siding, unloaded on the platform, distributed and wet down. This was pulled out and another followed with the proper amount of mixed sand and gravel. As soon as the last was unloaded, spread over the rocks and wetted, the barrels of cement were rolled across the flats, broken and distributed. Mixing with shovels then began, each turn bringing the mixture nearer the point of use, at which point the platform planks were removed so that the concrete dropped through to the rammers. For the north side, small removable troughs were used until such a height was attained that barrows were necessary. This arrangement enabled us to build the greater part of the mass with little use of barrows, but from a height of four feet from base of rail up, all the concrete was put in with wheelbarrows. The mixing board was near the track below the wall. The men made a circuit with the barrows. When each man returned to the mixing board with an empty barrow, another filled was ready for him, so that there was no waiting for loads. Tamping was done with point rammers weighing ten pounds each. Segments and lagging were made of two-inch plank, falsework of 12 x 12 inch timber. The tunnel is made sufficiently large to enable us to broad-gauge the road at any future time. The work occupied about six weeks, about one month being required for putting in concrete. The entire work contained about four thousand cubic yards of concrete. Exclusive of moulds, the concrete cost $6.00 per yard in place; to which the moulds would add 20 per cent. per yard. The falsework was allowed to remain during the winter of 1893–4, but was removed during last summer. Up to this date the structure shows no cracks or other sign of failure, and is apparently good for all time.

DISCUSSION.

THE PRESIDENT.—This is a very interesting account of the troublesome work on the Santa Cruz Road. It ought to be interesting to the civil engineers present, and I hope the paper will be discussed.

MR. MANSON.—Mr. President, I heard Mr. Isaacs give a general description of this work when it was in progress. It was of great interest at that time, and now it is of more interest, the work having been successfully completed, and so well described.

I would ask Mr. Isaacs why he did not use the large rock above the level of the track in the wall? Was it because of the diminished thickness of the wall, or because it was more desirable to have the wall above the track constructed homogeneously?

Mr. Isaacs.—It was for both reasons.

Mr. Dickie.—What was the effect on the cost? I presume that was the main factor in using them?

Mr. Isaacs.—I put the rock in for about sixty cents a yard and the concrete would cost eight dollars a yard. I do not see the sense of breaking up rock and cementing it together again, where you can use large masses. I could not see any reason why below the line of thrust we could not use almost anything sufficient to sustain the weight.

Mr. Manson.—I asked the question because I have always been a strong advocate of using heavy masses of rock in heavy masonry, where the rock is sound. In some instances, where I could get large rock, I have used it freely. In certain cases its use materially reduces the cost, and with good results.

Mr. Randell Hunt.—Has there been any movement of the side-hill or the top?

Mr. Isaacs.—Not that I have observed. I have examined it several times. Some of the cracks above the actual slide seem to have settled together, but I think more from weathering than anything else.

Mr. Hunt.—About how far back did you notice the movement in the hill?

Mr. Isaacs.—The actual slide was, at the farthest point, about four hundred feet back. We could trace cracks for half a mile up the side of the mountain.

Mr. Hunt.—Was it a rocky side hill?

Mr. Isaacs.—It was of decomposed rock, mixed with clay: a bluish-black clay; and under that was a stratum of hard country rock, pitching nearly in the direction that the slide took.

Mr. Hunt.—Did you take any means to drain the side hill afterwards—up on the hill?

Mr. Isaacs.—No, except through the dam.

Mr. Grunsky.—I would like to know what water was developed or what water was moving between the clay and the rock. We have recently had occasion to consider that question in the building of an earth dam with a rock foundation. We put in what might be called a core wall as a support for the earth dam. Just above the wall we put in some dry rock filling to create a sort of sump, and above that some

finer material. Then we put in a lead pipe from that sump to the toe of the dam, to show what was going on underneath the structure. The work seemed to have been satisfactorily done. There was really no leakage, and no water reached our broken rock at all. This may be an instance where it is possible to determine what the flow was between the clay and hard rock underneath it.

Mr. Isaacs.—I was at Wright's last winter, and I noticed there was some little dripping from the pipes that had been put into the rubble backing. Whether it got through the clay, or whether it followed down the concrete, I do not know. There was quite a little stream running from each of the pipes that were put through the puddle.

Mr. Hunt.—Mr. Chairman, this paper of Mr. Isaacs, which he has presented so clearly, brings to my mind some experiences I have had at various times with regard to very large clay slips, and particularly in railroad practice. I know of instances of alluvial deposits in rivers, where a clay bank on the concave shore is continually slipping forward, and railroads constructed along such a river bank have frequently met with mishap, due to the sliding forward of these large clay banks.

The usual remedy is in the nature of preventing such slips by drainage of the sidehill quite a distance back from the works. That is the reason I asked Mr. Isaacs whether he attempted anything of that kind to prevent future action. The cause of these great movements of sidehills and clay slips I have found to be water, which gets into the soil and seeks an outlet, generally through some permeable stratum. In the Red River Valley in North Dakota, a large area of land, embracing probably fifteen or twenty acres, slid forward, not quickly, but during a number of years, until it got down to an exceedingly flat slope. Nevertheless, it continued to move forward and carried with it a large bridge pier that was founded on piles forty feet in the ground. In seven years it moved about ten feet, so that the pier, which was under the end of a Howe truss bridge, was pushed under the second panel point. The movement was perfectly irresistible. No method, as far as could be seen, could be used to hold it back.

I know of a case also in California, in the mountains of Mendocino County, on Eel River. The side of the mountain started to move. It was due to water getting into the sidehill quite a distance back from the river, and it was pushing the whole side of the mountain down into the river. In this case any further progress was prevented by a very simple method of draining the sidehill about a thousand yards back. A few cross ditches carried the water away, and since then no further movement has been discovered.

Mr. Isaacs.—Before this work at Wright's Station was undertaken we discussed the matter of drainage pretty thoroughly. This tunnel had always given trouble in the heaviest winters. This section of country (I think Mr. Manson and Mr. Grunsky will bear me out) has about the heaviest rainfall of any section in California on the line of the Southern Pacific Railroad except Mount Shasta. We had already attempted to prevent the sliding by ditches, just beyond the gap, leading off both ways according to the slopes of the ground to the side creeks. But that did not stop it. The difficulty here seemed to be that the mountain side was composed of a broken-up soil, consisting of fine, decomposed rock and clay and various other materials, all mixed up together, and it lay on a pitching bed of rock. This mass was left with perpendicular sides and no toe, and it simply slid along. In the time at our disposal, with ground of such character, and with a large rainfall, we could not put in enough ditches to intercept the rain and prevent it getting down into the crevices. All sorts of suggestions were made about this work. One suggestion was to build a shed over the whole mountain side and keep the rain off.

Mr. Hunt.—Such slides occur where the water gets in behind and then sweeps down underneath the surface strata. I have usually found these slides in a clay bank, and where there are permeable strata. In one particular instance I argued that a stratum of sand was causing the trouble. We were sinking a large circular pier, thirty-two feet in diameter, and this clay bank was coming in on us. After we got down quite a distance, we came into a stratum of river quicksand a few inches in thickness, and this, no doubt, was the cause of the slip. The water got behind and into the clay, and the whole bank moved forward on the slide thus formed.

It has been my experience that blue clay seems to be the most slippery, and that the most irresistible slides are those caused by it.

In one case, when we had a very bad drought, the next season the bank moved more than usual. That was probably due to the fact that during the drought the heat cracked the clay bank, so that they were more apt to break open and leave fissures in the ground; then the rain would come on afterwards, the fissures would fill up with water, and the hydrostatic pressure would become enormous. I suppose this is the cause of nearly all these slips.

Mr. Manson.—The matter of sliding hillsides is exceedingly interesting here in California. You find it not only along the line of newly constructed works, but along creeks. On hillsides and on mountain sides the evidence of it is very distinct, and very interesting to study.

The California clays, and particularly those that are the result of

the decomposition of an impure soapstone we have here, are very apt to slide. Mr. Schussler says, he believes they would slide up hill. He has had very disastrous experiences with them in connection with his pipes.

Mr. Hunt.—A very large slide took place in Germany some years ago, and it was very successfully treated by means of a deep ditch on the upper side. It was carried underneath the railroad embankments, and side lateral ditches were run in both ways parallel to the railroad.

DEFLECTIONS AND STRAINS IN A FLEXIBLE RING UNDER LOAD.

By William H. Searles, C.E., Member of the Civil Engineers' Club of Cleveland.

[Read before the Club, July 9, 1895 *.]

If we suppose a flexible ring of uniform section to stand vertically, resting on a single point, and to be loaded at the top, a number of interesting problems at once present themselves for solution, such as:

What load will be required to produce a given depression?

What will be the horizontal extension of the ring under the same load?

What is the relation between the vertical and horizontal displacements?

What is the general relation between loads and vertical depressions?

What are the principal moments of resistance, at the side and top?

What is the position of the section of no moment at any period of deflection?

What is the radius of curvature at the side or at the top under any condition of load or depression, and at what point of depression does the radius of curvature become infinite?

Again, the same questions arise if we suppose the load to be replaced by a vertical pull, changing the ring from a roller into a link.

The Club has already listened to a paper on the compressive strength of steel hoops by Prof. C. H. Benjamin,† the publication of which led Messrs. C. W. L. Filkins and Edwin J. Foot, Civil Engineers of Cornell University, to offer an elaborate mathematical analysis of the conditions of a rigid ring under external load. Their conclusions and formulas, though applicable only to a ring which remains sensibly circular under load, are adopted here and form the basis or starting point of the present investigation.

The experimental data were derived from a ring of No. 9 steel wire electrically welded, having a mean diameter of 20 inches. The ring was compressed one quarter inch at a time, the load read on a spring balance, and the shape of the hoop traced at each inch of compression, the geometric center of figure being kept identical in all cases.

* Manuscript received September 25, 1895.—*Secretary, Ass'n of Eng. Socs.*

† Journal for December, 1893.

The ring was also subjected to tension, and a record of forces and shapes made in a similar manner. These experiments, though crude enough, were satisfactory up to the limit of elasticity. Beyond that point they were supplemented by experiments upon hoops of band-steel which would bear entire collapse under pressure, reducing one diameter to zero, and yet would recover their original shape fairly well.

As the figure of the hoop is always symmetrical about its two principal axes we may confine our attention to a single quadrant, taking the origin of co-ordinates at the center of the entire figure, and calling the vertical semi-diameter, Y, and the horizontal semi-diameter, X. For the circle, $Y=X=R$. Let $\triangle Y$ denote the compression due to a

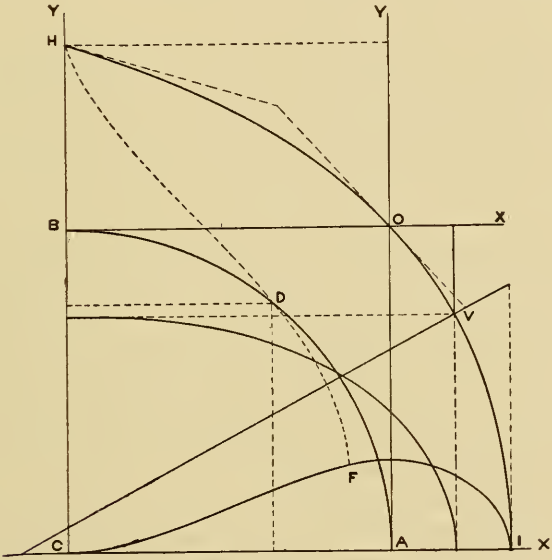

FIG. 1.

load and $\triangle X$ the horizontal extension, while the center C remains stationary. Suppose the vertical radius to be divided into ten equal parts and the hoop compressed successively to each point of division. We shall then find that X has been extended by ten unequal increments which gradually decrease toward the end of the experiment. If we extend Y by equal increments, X will be reduced by rapidly increasing increments. If we draw perpendiculars through the corresponding points of division, their intersections will lie in a curve. (Fig. 1.) This curve, of course, passes through the point O where the tangents to the circle meet, it crosses the axis of Y at H, CH being equal to the length of the quadrant and is the value of Y when $X=O$. The curve also cuts the

axis of X at I, when $Y=O$. The tangent at I is assumed to be at right angles to CI.

To find the tangent at O we refer to the paper above mentioned which demonstrates that if $\triangle X$, $\triangle Y$, represent the first minute changes in the value of the radius R of a circular ring under a load P, then

$$\triangle X = \frac{4-\pi}{4\pi} \cdot \frac{P R^3}{E I} \text{ and } \triangle Y = \frac{\pi^2-8}{8\pi} \cdot \frac{P R^3}{E I}. \tag{1}$$

Consequently, if i is the inclination of the required tangent at O to the axis of Y, we have by division,

$$\tan i = \frac{\triangle X}{\triangle Y} = \frac{8-2\pi}{\pi^2-8} = .91828 \tag{2}$$

or $i = 42°33'38,''$ a constant, and therefore true, for all hoops. Having now three points through which the curve of XY passes and the direction of the tangents at two of them we determine by graphical tests that this curve can only be a common parabola, but its axis does not pass through our origin C, nor is it parallel to either axis of co-ordinates.

The finding of the axis of the parabola, its focus, etc., by analysis is a neat little problem, which, however, need not be gone into here. Suffice it to say that, $C\,H$ being equal to $R\ \frac{\pi}{2} = R\ 1.5708$, and $C\ I$ equal to $R\ 1.3673$ and the tangents to the curve at O and I being as stated, the axis of the parabola is inclined to the axis of X by an angle of $28°\ 33'\ 49''$ and cuts the axis of X at a point $.14461\ R$ beyond or to the left of the origin C. The co-ordinates of the vertex V are $X = 1.19450\ R$, and $Y = .72900\ R$. The parameter is $2p = 2.6558\ R.$, in which R is the mean radius of the original hoop.

This parabola solves the third question of the series, giving by its co-ordinates the relation between the vertical and horizontal displacements. The calculation of value of $\triangle X$ in terms of $\triangle Y$ is rather tedious. The equation of the curve, referred to the axes $X\ Y$, is too complex for convenient use, but a double transformation of co-ordinates is practicable. Taking the origin for $\triangle X$, $\triangle Y$ at O, and taking the origin for the co-ordinates $\triangle Y$ of the parabola at its vertex V, and letting a, b represent the distance between origins measured on $\triangle Y$, and $\propto$ the inclination of the axis to X as given above, then for any value $\triangle Y$ corresponding to the point M on the curve between O and V we have

$$(b-\triangle Y) = y \cos. \propto - x \sin. \propto$$

But for the parabola $x = \dfrac{y^2}{2p}$

$$\therefore \quad y = p \cot. \alpha - \sqrt{p^2 \cot.^2 \alpha - \frac{2p(b - \triangle Y)}{\sin. \alpha}} \tag{3}$$

from which value we find that of $x = \frac{y^2}{2p}$ and finally

$$\triangle X = a - (x \cos. \alpha + y \sin. \alpha) \tag{4}$$

The same formulas apply to any point M on the curve above O or below V, with suitable change of signs. Having calculated a series of values of $\triangle X$ we have only to add them to R, (or subtract for points above O) to obtain the values of X referred to the origin C, since the ordinate $\triangle X = X—R$. By this method all tabulated values of X given below have been calculated. The parabola below O represents compression (Y less than R) and above O extension (Y greater than R). It applies to all circular rings of whatever section or diameter. Its determination, as we have seen, is a purely geometrical problem, being independent of the amount of force or load required to produce distortion in the ring. Its form is always the same. If drawn to scale for a ring of unity, its ordinates $\triangle X$ $\triangle Y$ multiplied by the radius of another ring will give the amount of distortion for the latter.

To investigate the law governing the loads required to produce a given series of depressions, reference was had to the experiments made upon the 20-inch ring. Drawing a vertical line OA, 10 inches long to represent the radius, and dividing each inch into eighths, horizontal lines were drawn through the points of division, on which were laid off, to a scale of ten pounds to an inch, the actual loads deduced by experiment. A line drawn through the extremities of these ordinates approximated a curve, the character of which was not obvious at first, owing to the permanent set that occurred in the ring as the load increased.

To find the tangent to the force-curve at O, where the load P equals zero, we quote again from the Cornell paper the equation giving the relation between the load and depression while the ring remains circular, viz:

$$\triangle Y = \frac{\pi^2 - 8}{8\pi} \cdot \frac{PR^3}{EI}.$$

If in this, we replace P by $\triangle P$ to represent the load producing the first indefinitely small depression $\triangle Y$, and then multiply $\triangle P$ by $S.$ ($=10$) to reduce inches to pounds, we have:

$$\triangle Y = \frac{\triangle P.S.R^3}{EI} \cdot \frac{\pi^2 - 8}{8\pi}$$

Now dividing by $\triangle Y$, and letting $u =$ the inclination of the tangent line to the vertical:

$$\tan. u = \frac{\triangle P}{\triangle Y} = \frac{8\pi}{\pi^2 - 8} \cdot \frac{EI}{SR^3} \tag{5}$$

An examination of the form of the hoop as traced at certain stages of the experiment showed that at one stage of depression the top of the hoop becomes perfectly flat, although loaded at a single point, and this was found to occur exactly at the level of V, the vertex of the parabola. With any increase of load after this, the curvature is reversed in the top of the hoop, and when the hoop is entirely collapsed, or $Y = o$, the radius of curvature appears to be just one-half of the original radius R.

Now it is a well-known principle of mechanics, that if an elastic straight bar be bent into a circular form and the ends united, the ring will be, theoretically, a perfect circle, and a moment of resistance will be developed in every section of the material tending to restore the ring to a straight line the instant that the ends are released. This uniform moment is expressed by $\frac{EI}{R}$, or the product of the modulus of elasticity into moment of inertia of the cross-section divided by the mean radius of the ring.

Conversely; if an elastic ring, normally circular, be so compressed as to reduce a portion of it to a straight line, the moment of resistance developed in that portion will be $\frac{EI}{R}$ as before. And if the pressure be increased until the radius of reversed curvature becomes equal to the original radius the moment of resistance of the section will then be $2\frac{EI}{R}$. If by further pressure the reversed radius be reduced to one-half the original radius the resulting moment will be increased to $3\frac{EI}{R}$; and so on.

If then M_B represents the variable moment at the section B,

For level of	B	$\triangle Y = 0$	$M_B = 0$	$R_B = R$
"	V	$\triangle Y = .2709974R$,	$M_B = \frac{EI}{R}$	$R_B = \infty$
"	?	$\triangle Y = ?$	$M_B = 2\frac{EI}{R}$	$R_B = - R$
"	C	$\triangle Y = R$	$M_B = 3\frac{EI}{R}$	$R = - 2R$

and in general

$$M_B = \left(1 - \frac{R}{R_B}\right)\frac{EI}{R} \tag{6}$$

in which $R_B =$ the variable radius of the hoop at the point of application of load.

We thus know the value of the moment M_B for three positions of the point of application of force, and if we knew the lever arm in each case we could calculate the force exerted.

Now the Cornell paper demonstrates that for a rigid circle the sum of the two principal moments (at A and B) is

$$M_A + M_B = \frac{PR}{2}$$

As the flexures at A and B are contrary, there must be, on the quadrant between them, a point of no flexure, and consequently of no moment. This point is proved to be at D, the horizontal ordinate of which is $\frac{2}{\pi}R$.

The point D is the center of moments for the circular ring, and $\frac{2}{\pi}R$ is the lever arm for the moment at B. Therefore, for the circle,

$$\left.\begin{aligned} M_B &= \frac{PR}{2}\cdot\frac{2}{\pi} = \frac{PR}{\pi} \\ M_A &= \frac{PR}{2}\left(1 - \frac{2}{\pi}\right) \end{aligned}\right\} \qquad (7)$$

A careful study of the several shapes of the ring, traced at successive stages of compression, served to locate with considerable accuracy the point in each case where the radius of curvature was equal to the original radius R. These points taken together gave a fairly regular curve, and an average curve drawn among them was taken to be the curve of no moment, or the *locus* of the center of moments for all stages of compression. See $H\ D\ F$, Fig. 1.

It was then discovered that the horizontal ordinate to the intersection of the *locus* with the compressed ring bore a constant ratio to the value of X for the same stage of compression (X being the horizontal semi-diameter); and that this ratio is identical with the ratio established by theory for the lever arm in the circle. Calling the two lever arms at any stage X_A and X_B, respectively,

$$X_A + X_B = X$$

$$X_B = 2\frac{X}{\pi} \text{ and } X_A = X\left(1 - \frac{2}{\pi}\right) \qquad (8)$$

Consequently

$$M_B = \frac{P}{2}\cdot\frac{2X}{\pi} = \frac{PX}{\pi} \qquad M_A = \frac{PX_A}{2} = \frac{PX}{2}\left(1 - \frac{2}{\pi}\right) \qquad (9)$$

The discovery of the permanence of this ratio is probably the most important one in the whole investigation. We have now only to resolve the last formula to obtain

$$P = M_B\frac{\pi}{X} \qquad (10)$$

Giving to M_B and X the particular values found for them for the level of the vertex V, we obtain the corresponding value of P; similarly we find the value of P for the state of collapse, and plotting these two values to scale we have two definite points, W and J, on the force-curve (Fig. 2), besides the point O, and the direction of the tangent at O. Drawing a curve through these points and through other points near O obtained by direct experiment, it became evident that the force-curve is an hyperbola. It was also evident that the vertex lay a short distance above the level of B, and that the axis through the vertex passes not far from the center C of the circle. The three known points of the

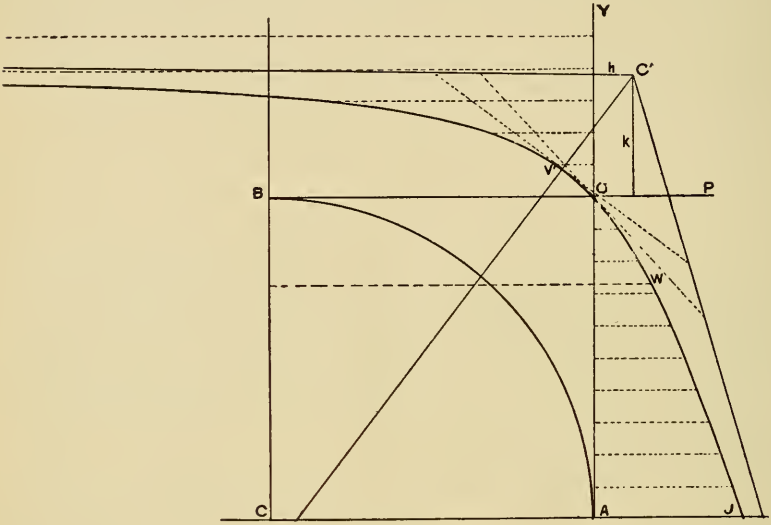

FIG 2.

hyperbola are therefore all on one side of the axis, and the hyperbola beyond the vertex is given only approximately by experiment.

But if we consider the moments induced in the section A, we see that no amount of vertical tension applied at B can do more than straighten the ring at A; consequently the moment M_A can never exceed the limit $\frac{EI}{R}$; and this limit is only reached when the ring is drawn out to a straight line, and X is reduced to zero. At the same time the moment M_B under tension increased indefinitely by the action of the same force that produces M_A. It is obvious that the lever arms X_A X_B cannot maintain an invariable ratio on the tension side as they do on the compression side, but X_B must increase at the expense of X_A while their sum is always equal to the variable quantity X, the mean semi-diameter of the link. The change of ratio does not begin, however,

until the level of the vertex V' of the hyperbola is reached and is not perceptible until $Y = 1.10\ R$. At or near this point the curve of moments M_A undergoes reversion, and it finally becomes tangent to a line parallel to the axis of Y at a distance from it equal to $\frac{EI}{R}$ when Y reaches its maximum of $\frac{\pi}{2} R$.

This curve of M_A was drawn tentatively at first on the tension side, as also the curve of P; and $X_A = \frac{M_A}{\frac{1}{2}P}$ determined for a number of points. Then $X_B = (X - X_A)$ was found, and finally $M_B = \frac{P}{2} X_B$. The half load only is employed, because by supposition the load P is equally divided between the two sides of the ring, and we are considering only one side. After a number of trials, a set of curves for loads and moments in tension was arrived at that seemed to satisfy all conditions reasonably well.

The force-curve is required in any case to pass through the given points O, W, J, and to have a tangent at O, making the given angle u with the axis of Y. Any change in the assumed position of the vertex V' or direction of axis $V'\ C'$ would make very slight impression on the compression side of the curve while making a wide divergence on the tension side. Experiments are needed in the high tensions upon a ring of great elasticity, to fix definitely a few points well out on the tension end of the force-curve, but in their absence the present results are offered as fair approximations through the whole range, and very close to the truth on the compression side, and as far as $1.10\ R$ in tension.

The axis of the hyperbola can have but one direction for a given position of the vertex, otherwise the angle u would be altered, yet the relation between them is not easily expressed. Having decided upon the direction of the axis, or the angle β that it makes with OY, the position of the vertex was found, after a few trials, such as to give u the required value.

The value of the modulus of elasticity of the steel wire in the experimental ring was taken at,

	$E = 28{,}666{,}890$	[7.4573805]
and the moment of inertia		[5.3720167]
Hence $EI =$	675.1452	[2.8293972]
$\frac{EI}{10R^3}$	.06751452	[8.8293972]
The constant $\frac{8\pi}{\pi^2 - 8}$ is		[1.1284902]
$\therefore$ tan. $u =$ tan. $42°\ 13'\ 35''.11$		[9.9578874]

Calling the force required to compress the hoop to the level of V, P_1 :—

$$P_1 = M_B \frac{\pi}{X_1} = \frac{EI}{R} \cdot \frac{\pi}{X_1} = \qquad 17.75658 \qquad [1.2493594]$$

If P_2 is the force required to collapse the hoop to the level of the center:—

$$P_2 = M_B \frac{\pi}{X_2} = \frac{3EI}{R} \cdot \frac{\pi}{X_2} = \qquad 46.53673 \qquad [1.6677959]$$

since $X_1 = 11.945042$ and $X_2 = 13.67325$ for the parabola, as we have already seen. The values of P_1 and P_2 are thus calculated independent of experiment as soon as E is determined, and since the ordinates representing them are plotted to the scale of $\frac{1}{10}$, we must take one-tenth their value as the ordinates to the hyperbola.

The direction finally fixed upon for the axis of the curve makes an angle with the axis of Y of $\beta = 37° 15'$ on the opposite side from the angle u. The next step is to calculate the semi-axes, a and b, of the hyperbola passing through the three given points, with the given tangent at O, to locate the center and vertex, and to find the co-ordinates $x_0\ y_0$, $x_1\ y_1$ and $x_2\ y_2$ of the three given points, referred to the axis and center of the hyperbola. Not to burden this paper with these mathematical pyrotechnics, let us assume this work accomplished, and we find as results :

y_0	1.291056	[0.1109451]	x_0	3.758851	[0.5750551]
y_1	4.344814		x_1	4.841201	
y_2	11.048329		x_2	8.902030	

For the semi-axes:

$a = 3.636958$	[0.5607383]	$b = 4.945402$	[0.6942016]

Note that a is less than b, showing that this is what is usually called a conjugate hyperbola.

If we let h and k stand for the co-ordinates of the center referred to the origin at O and axes XY, then :

$h = 1.247527$		$k = 3.773522$	[0.5767469]

With these quantities we may construct the hyperbola and scale off the horizontal ordinates at any point above or below O corresponding to $\pm \triangle Y$, the ordinate giving one-tenth $(\pm P)$ in each case.

To calculate P for any exact value of $\triangle Y$ we resort, as in the case of the parobola, to a double transformation of co-ordinates. Assuming $\triangle Y$ giving a point M, on the hyperbola, find x, then y, and from these find $\frac{P}{10}$ for the same point M.

The formulas for this calculation for points below O, or when P is positive, are:

$$x = -(k + \triangle Y)\, A \cos.\beta + \sqrt{(k + \triangle Y)^2 \left[A^2 \cos.^2 \beta + A\right] + A b^2 \sin.^2 \beta} \qquad (11)$$

in which $\quad A = \dfrac{a^2}{b^2 \sin.^2 \beta - a^2 \cos.^2 \beta}$, a constant ratio,

$$y = \frac{(k + \triangle Y) - x \cos.\beta}{\sin.\beta} \quad \text{or} \quad y = \sqrt{\frac{b^2}{a^2}(x^2 - a^2)}, \qquad (12)$$

and

$$\left(\frac{P}{10} - h\right) = y \cos.\beta - x \sin.\beta. \qquad (13)$$

The same formulas, with suitable change of signs, apply to finding P in tension, or $-P$. By this method all the values of P were obtained, as given in the following table:

TABLE I.—Values Derived from Experimental Ring.

$R = 10. \qquad EI = 675.1452.$

Y	P lbs.	X ins.	M_A	M_B	R_A ins.	R_B ins.
	—	+	—	—	+	+
15	819.9721	2.0980	67.301	792.85	3154.6	.7847
14	305.0290	4.4367	65.613	611.04	354.99	.9950
13	82.0106	6.2787	58.667	198.80	76.278	2.5322
12	30.8645	7.7679	41.188	78.688	25.645	4.6178
11	11.1886	8.9898	18.275	32.018	13.711	6.7833
10	0.	10.	0.	0.	10.	10.
9	+ 7.8199	10.8372	+ 15 3975	+ 26.975	8.1429	16.6544
8	13.9771	11.5295	29.279	51.296	6.9721	41.611
7	19.1993	12.0883	42.203	73.935	6.1535	± ∞ 105.152
6	23.8400	12 5600	54.404	95.313	5.5377	24.283
5	28.0967	12.9278	65.995	115.622	5.0647	14.035
4	32.0867	13.2123	77.027	134 947	4.6710	10.0125
3	35.8845	13.4223	87.512	153.316	4.3550	7.8686
2	39.5380	13.5651	97.447	170.722	4.0927	6.5415
1	43.0805	13.6470	106.820	187.141	3.8728	5.6435
0	46.5367	13.6733	115 614	202.545	3.6867	.5

The values of the moments M_A, M_B are the products of $\frac{1}{2}PR$ by the respective lever-arms X_A, X_B which are given in Table II. Although the bending at A and B is contrary, one being outward when the other is inward, the moments at A and B take the same sign; *viz.* the sign of of P whether $+$ or $-$, since the lever-arms are considered positive throughout, and the two moments conspire to resist or balance the load at any instant.

The last two volumes give respectively the radius of curvature of the bent hoop at the points A and B. Under tension the radius R_A increases from 10 to infinity, while under compression it is diminished to 3.6867 for $Y = 0$, or $\triangle Y = 10$. The radius of curvature R_B, on the contrary, is decreased theoretically to zero under tension when $Y = 15.708$, but under compression increases rapidly to infinity when $Y = 7.290026$, and then, changing sign it is reduced from $-$ infinity to -5, or $-\frac{1}{2}R$, when $Y = 0$. When $Y = 4$ the value of R_B is -10.0125, or $-R$ very nearly. The formulas for obtaining R_A and R_B will be given later.

Since Table I only contains values applicable to the experimental ring it would seem at first to serve no purpose other than to illustrate the subject, but as we shall now see, we may from this construct a table applicable to all cases.

Taking any one line of the table and regarding the quantity in the first column merely as a proportional part of radius R, we observe from the preceding formulas that, when R is constant:

P varies as EI, X is constant, and M_A, M_B vary as EI.

But if EI is constant and R variable:

$$P \text{ varies as } \frac{I}{R^2}, X \text{ varies as } R, \text{ and } M_A, M_B \text{ vary as } \frac{1}{R}.$$

Therefore by combination; in general,

$$P \text{ varies as } \frac{EI}{R^2}, X \text{ varies as } R, \text{ and } M_A, M_B \text{ vary as } \frac{EI}{R}.$$

Now let Y be divided by R, to get Y of Table II. Let $K = \frac{PR^2}{2EI}$, taking R and EI from the head of Table I. Find X_A, X_B from X by equation (8), first dividing X by R, Table I, and place all the results in Table II. These are values corresponding to $R = 1$ and $EI = 1$; but $K =$ the *half* load.

If then we let A, B, be the principal moments for $R = 1$ and $EI = 1$ we have at once $A = KX_A$, and $B = KX_B$. Or we may obtain A, B, by multiplying M_A, M_B, each by $\frac{R}{EI}$. Table I.

To find the radius of curvature at B, we have from equation (6)

$$M_B = \left(1 - \frac{R}{R_B}\right)\frac{EI}{R}$$

whence

$$R_B = \frac{R}{1 - M_B \dfrac{R}{EI}}$$

and when

$$R = 1 \text{ and } EI = 1 \qquad R_B = \frac{1}{1 - B}$$

Similarly we may derive

$$M_A = \left(\frac{R}{R_A} - 1\right)\frac{EI}{R}$$

whence

$$R_A = \frac{R}{1 + \dfrac{RM_A}{EI}}$$

and when $R = 1$ and $EI = 1$, $R_A = \dfrac{1}{1 + A}$.

In using A and B in these formulas, their algebraic signs must be regarded.

We may now prepare the following table, for general use:

TABLE II.—VALUES PERTAINING TO AN ELASTIC RING.

In which $R = 1$ and $EI = 1$.

Y	K	X_A	X_B	A	B	R_A	R_B
	−			−	−	+	+
1.5	60.726	.016416	.19339	.99683	11.7435	315.46	.078741
1.4	22.590	.043021	.40065	.97183	9.0504	35.499	.099498
1.3	6.0735	.143064	.48481	.86890	2.9415	77.6278	.25352
1.2	2.2857	.266895	.50990	.61006	1.1655	2.5645	.46178
1.1	0.82860	.326672	.57232	.27068	.47423	1.3711	.67833
1.	0.	.363380	.636620	.0	.0	1.	1.
	+			+	+	+	+
.9	0.57913	.393802	.689917	.22806	.39955	.81429	1.66541
.8	1.01312	.41896	.73399	.43367	.75977	.69751	4.1611
							$\pm\infty$
.7	1.42185	.43963	.77020	.62503	1.0951	.61535	10.5152
.6	1.76554	.45641	.79959	.80580	1.4118	.55377	2.4283
.5	2.08079	.46977	.82301	.97748	1.7125	.50647	1.4035
.4	2.37628	.48011	.84112	1.14088	1 9987	.46710	1.00125
.3	2.65755	.48774	.85449	1.29620	2.2709	.43550	.78686
.2	2.92817	.49293	.86358	1.44334	2.5287	.40927	.65415
.1	3.19046	.49590	.86880	1.58216	2.7718	.38728	.56438
0.0	3.44642	.49687	.87045	1.71242	3.	.36867	.5

K in lbs. A and B in lbs.-inches. The others in inches.

In order to apply Table II to any elastic ring of radius R, and elastic reaction EI, we have only to observe the following rules:—

To find the total load, $P = K \frac{2EI}{R^2}$.

To find the lower arms X_A X_B, multiply the tabular numbers by R.

To find the semi-diameter X, add together the lower arms just found.

To find the principal moments M_A M_B, multiply A and B of the table by $\frac{EI}{R}$.

To find the radius of curvature at A or B, multiply R_A or R_B (Table II) by R.

We are thus able to solve the problem of the elastic ring through the whole range of distortion, or as far as the elastic limit of the material will permit. Interpolated values may be used if necessary, in which case the second order of differences should be employed to secure accurate results.

TABLE III.—VALUES PERTAINING TO AN ELASTIC RING.

In which $R = 1$, and $EI = 1$.

$\triangle Y$	K	$\triangle X$	A	B	R_A	R_B
+	—	—	—	—	+	+
.10	.82860	.10102	.27068	.47422	1.37114	.67833
.09	.72752	.09004	.24056	.42145	1.31677	.70351
.08	.63150	.07927	.21129	.37016	1.26789	.72984
.07	.54009	.06869	.18278	.32021	1.22365	.75745
.06	.45288	.05832	.15497	.27150	1.18339	.78647
.05	.36950	.04814	.12781	.22391	1.14654	.81705
.04	.28964	.03814	.10124	.17736	1.11264	.84936
.03	.21301	.02834	.07521	.13176	1.08133	.88358
.02	.13934	.01871	.04969	.08705	1.05228	.91992
.01	.06841	.00927	.02463	.04315	1.02525	.95864
.00	.0	.0	.0	.0	1.	1.
—	+	+	+	+	+	+
.01	.06607	.00910	.02423	.04244	.97635	1.04433
.02	.12998	.01803	.04808	.08424	.95412	1.09199
.03	.19187	.02679	.07159	.12542	.93319	1.14341
.04	.25190	.03539	.09477	.16604	.91343	1.19909
.05	.31017	.04383	.11765	.20612	.89473	1.25963
.06	.36682	.05211	.14024	.24569	.87701	1.32572
.07	.42195	.06024	.16256	.28480	.86017	1.39821
.08	.47564	.06821	.18463	.32346	.84415	1.47811
.09	.52801	.07604	.20646	.36170	.82887	1.56667
.10	.57913	.08372	.22806	.39955	.81429	1.66541

K in lbs. A and B in lbs.-inches. The others in inches.

As most cases requiring solution will be concerned with a distortion $\triangle Y$ not exceeding $\pm \frac{R}{10}$, Table III has been prepared within these limits.

To find the limiting load, the maximum fibre-stress must be considered. If this be represented by p and the half thickness of the ring or pipe by e, since

$$M_B = \frac{pI}{e} = B\frac{EI}{R}$$

$$p_B = B\frac{Ee}{R} \text{ and } p_A = A\frac{EI}{R}$$

At A we have also the unit-stress of the half-load $\frac{P}{2}$ divided by the area, but this is relatively quite small. Since the ratio of B to A or p_B to p_A is never less than 7 : 4, and in high tension, much greater, p_B is greater than the sum of the unit stresses at A. There is neither thrust nor tension at B, but there is a shear, equal to half the load, near the point of application.

If we assume a limit for p we first find B by

$$B = p\frac{R}{Ee}$$

and opposite value of B in the table we find the other values required Thus taking the limiting value of the half load K for unity, we multiply it by $\frac{2EI}{R_2}$ to obtain the limiting value of P.

The hoop is assumed to preserve an invariable length under stress. It does so, sensibly in compression, and in moderate tension; but when pulled out into a flat link it will generally stretch so as to give results somewhat at variance with the theory of the elastic ring.

Unless the material is of uniform section and elasticity throughout it will yield most at the weakest point, thus disturbing the ratios of distortion, $\triangle X$ and $\triangle Y$. Hence in any experiment both principal diameters should be measured and compared.

We may now look at an application. A steel pipe of 8 feet 4 inches mean diameter, made of $\frac{3}{16}$ inch plate, lying horizontally and free. What load per lineal foot may be placed upon it so that it shall be depressed not more than one-tenth of its diameter?

$E = 29{,}000{,}000.$	log. 7.46240
In one foot of length $I = \frac{bd^3}{12} = \left(\frac{3}{16}\right)^3$	" 7.81900
Radius R 50	" 1.69897
$\frac{EI}{R}$	" 3.58243

$\triangle Y = .10,\ B$ .39955		log.	9.60157
$\therefore M_B = B\dfrac{EI}{R}$	1527.6	"	3.18400
$\dfrac{Ee}{R} = \dfrac{3}{32} \cdot \dfrac{29{,}000{,}000}{50}$		"	4.73540
$\therefore p_B$	21726.	"	4.33697
$\dfrac{2EI}{R^2}$		"	2.18449
$\triangle Y = .10,\ K$ .57913		"	9.76277
$\therefore P$	88.565	"	1.94726

Therefore the load per lineal foot must not exceed 88.5 pounds, and this will cause a maximum fibre-stress (at B) of 21,726 pounds per square inch. Of course, if the pipe has side support, as of earth in a trench, or if the load were distributed, the load might be greatly increased with safety.

Bradley & Poates, Engr's, N.Y.

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THE CONTINUOUS RAIL IN STREET RAILWAY PRACTICE.

BY RICHARD MCCULLOCH, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read before the Club, October 2, 1895.*]

IN one of Jules Verne's stories there is very happily described the rivalry between an armor maker and a cannon manufacturer. Mix, forge, temper and chill as he would, no sooner would the armor maker turn out a piece of steel which was an absolutely safe covering for a war ship, than the cannon maker would produce a gun to shoot through it. Much the same condition of affairs might be supposed to exist between the rail-mill and the car-factory.

In the horse-car days, flat tram-rail, laid on stringers, was used almost entirely, and when the girder-rail was rolled it was supposed that all that could be desired in the way of track had been produced. But when electric cars were put on the horse-car tracks and when the length of these cars was increased from eighteen to thirty-five feet, the weights from five thousand to twenty-four thousand pounds, the speeds from eight to twenty miles per hour, and the headway decreased from five minutes to less than one minute, the rail manufacturer found himself a thorough sympathizer with Jules Verne's armor-plate maker. For every inch that he added to the depth of his girder-rail, and for every improvement in its manufacture, an additional length was added to the car and an additional weight to the trucks and motors.

* Manuscript received October 25, 1895.—*Secretary, Ass'n Eng. Socs.*

The life of a girder-rail is supposed to continue until the head becomes so worn that the flanges of the wheels begin to run on the tread. But as a matter of fact, few street railway tracks last until this takes place, for long before the head is worn off, the joints have become so rough that the rail must be renewed to save wear and tear on passengers and cars. No matter how carefully and skillfully the track has been laid, sooner or later the inevitable bump begins to notify the unhappy manager that his track is composed chiefly of joints. What to do is then a question. He may at quite an expense put a gang of men to work tightening up the fish-plates, shimming up the joints, putting stringers and steel plates underneath the rail ends, etc., but all this is necessarily slow and expensive work. Worst of all, it affords only temporary relief, for the very bump by which the joint first notified the world at large of its vitality, has flattened the ends of the rails so that the track is never again perfectly smooth at that point. This roughness soon starts the hammering action of the wheels and in a short time the joints again assert their presence. The Science of Invention has not been laggard in this problem, for the records of the Patent Office will show that not even the flying-machine or street-car fender has been a more popular subject than the invention of perfect joints.

Exactly who was the first man bold enough to suggest having no joints at all is hard to say, but it is pretty certain that the first experimenting in this line was done by Mr. Philip Noonan, a railroad engineer of Lynchburg, Va., who several years ago built about three miles of steam-railroad track leaving no openings between the rails and fastening the joints with hot-riveted plates. This track was in actual use for several years and was the first demonstration of the continuous rail. Early in 1892, the Johnson Company, of Johnstown, Pa., under the leadership of its president, Mr. A. J. Moxham, began experimenting with the continuous rail. One rail of a section of track 1,160 feet long, was joined by heavy bars and machine fitted bolts so that there was no possibility of movement. Carefully fitted wedges were driven into the spaces between the ends of the rails, and every precaution taken to have the joint absolutely immovable. The other rail of the same track was laid in the ordinary manner with fish-plates and openings between the rails, so that any deviation of the continuous rail from a straight line would be noticed in the change of gauge. The rail used was the Johnson 6-inch, 78-pound girder, and the track was in actual use during the time of experimenting. At five points along the line, stakes were set opposite marks on the rails so that any change in the length of rail would at once be noticeable. Three times during the day and three times during the night, from March to September of 1892, temperature readings were taken of the following: air in the shade; road-bed at a

depth of seven inches; road-bed at a depth of ten inches; head of girder-rail and base of girder-rail. Observations were also made at regular intervals of the position of the marks on the rails with reference to the stakes. Briefly summing up the result of the experiment, we may say that the temperature of the rail followed very closely the temperature of the air, being slightly colder than the air during the day and slightly warmer during the night. The road-bed, being a poorer conductor of heat than the rail, was less affected by the changes of temperature of the air. During the period of experiment, the air temperature varied from 10 to 89 degrees, and absolutely no movement could be detected in the rails, either longitudinally or laterally. This experiment satisfied the Johnson Company that the continuous rail was practicable; and having proved its feasibility they at once set about finding the best method of uniting the rail ends. This was the first thorough and scientific experimenting done in connection with continuous rails; and, whether or not the particular method of connecting the rail ends advocated by the Johnson Company is the best one, all honor is due the officers of this company for the contribution they have made to the knowledge on the subject and the unselfish manner in which they have disseminated it.

ELECTRIC WELDING.

The method adopted by this company for connecting the rail ends was that of welding them electrically. A machine for this purpose was built by the Thomson Welding Company, and in the spring and summer of 1893 about three miles in Johnstown and about eight miles of track in Boston were electrically welded. During the winter of 1893–94 about six per cent. of these joints broke. Having remedied some apparent defects in the method, the Johnson Company in the spring of 1894 sent their machine to St. Louis, where six and a half miles of track were electrically welded. From St. Louis the machine was sent to Cleveland, where about five miles were welded, and then to Brooklyn, where thirty-two miles of track were joined together by this method.

The first track electrically welded, that in Johnstown and Boston, was not welded directly at the joint, but the rail ends were joined on each side by means of a span which was welded to the web of the rail about four inches back of the end. The breaks did not occur at the joint or in the span, but the rail itself broke where the span had been welded on. This was supposed to be due to the fact that when the rail at this point cooled after the welding process, internal strains were produced which seriously impaired the tensile strength of the rail at this point. A new form of joint was devised by means of which an actual butt weld is made at the joint, and this is the method which has been applied in St. Louis.

The Baden Division of the St. Louis Railroad Co., where the electric welding in this city was done, consists of three and one-quarter miles of double track and extends from the northern end of the Broadway cable to the vine-clad hills of Baden, in the extreme northern part of the city. The track throughout is laid in a macadam street, no paving being used either inside or outside the rail.

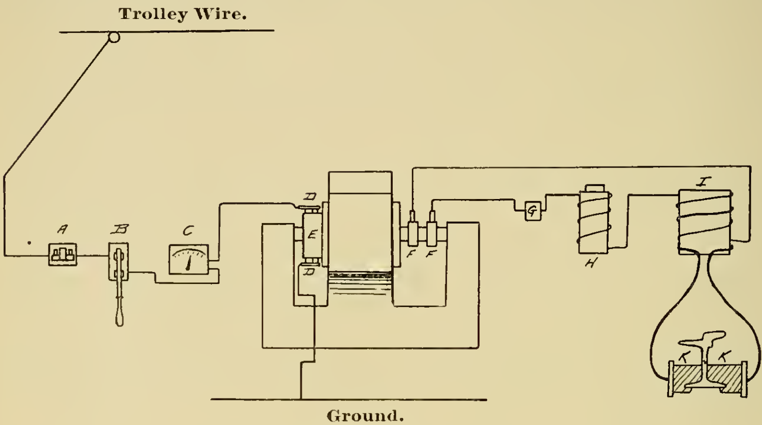

FIG. 1.—DIAGRAM OF WELDING CIRCUIT.

A Automatic Circuit Breaker.	*FF* Collector Rings.
B Switch.	*G* Break Switch.
C Ammeter.	*H* Reaction Coil.
DD Brushes.	*I* Welding Machine.
E Commutator.	*KK* Lugs for Welding.

A brief description of the welding apparatus will be given. This is mounted on a car having its own motors and controlling apparatus, so that it may move along the track by means of the trolley current. For the welding, the current passes through an automatic circuit breaker, switch, ammeter and starting rheostat to a rotary transformer which converts from 500 volt continuous to alternating current. The transformer is an ordinary four-pole, General Electric, 100 kilowatt-dynamo. To obtain the alternating current four leads from the windings are taken off at equal distances around the armature and led to the two collector rings on the armature shaft. The speed of the transformer is about 1,100 revolutions per minute, so that the periodicity of the alternating current is about 4,400 per minute. The alternating current from the collector rings passes through a reaction coil with a movable iron core to the welding machine. This is on the end of the car and is hung on a crane so that it may be set over either rail. It works on the principle of the well-known Thomson welders, and is simply an alter-

nating current transformer on a large scale, in which the rail joint completes the secondary circuit. The insulation of the coils is paraffine oil and the secondary consists of an enormous bundle of sheet copper strips. These strips lead to two contact plates between which the welding is done. The distance between the plates is controlled by a toggle joint operated by a screw, so arranged that by a slight turn of the screw a great pressure may be brought to bear on the weld. In addition to this circuit, the welding car contains a motor for driving the crane and another which operates a pump for circulating water in the welding machine. The car is very heavy, weighing about thirty tons when equipped for work. The outfit also includes a small car which carries two motors operating emery wheels for polishing the joints, preparatory to welding.

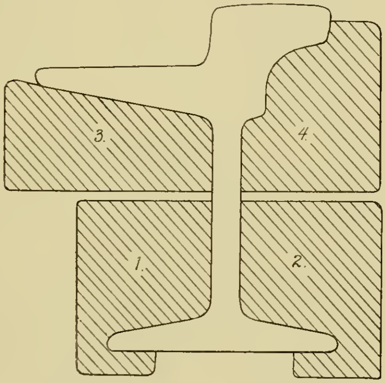

FIG. 2.—LUGS WELDED TO THE RAILS.

Nos. 1 and 2 welded at first heat. Nos. 3 and 4 welded at second heat.

The connection between the rail ends is made by lugs welded to the web of the rail. It is intended that enough plastic steel shall enter the joint to make a butt-weld, and that additional security is afforded by the lugs welded to the web. There are four lugs used at each joint and two welds are necessary, the bottom two being welded in one operation and the upper two in the next. During the welding operation, which lasts from one to two minutes, the direct current transformer takes from the line about 250 amperes at 500 volts. This is transformed down in the secondary of the welding machine to about four volts. The current which passes through the lugs on the rails is consequently 20,000 to 30,000 amperes.

The operation of welding is as follows: The ends of the rails are butted together by driving a wedge in the joint ahead, and the welding car is run over the joint to be welded, the welding taking place in the rear of the car, so that it is never necessary to run over a hot joint.

The webs of the rails are polished with emery wheels for about two inches to each side of their ends. The joint is clamped by means of a gun-metal casting, which holds the rails in proper position while the weld is being made, and the bottom lugs are then placed in position and

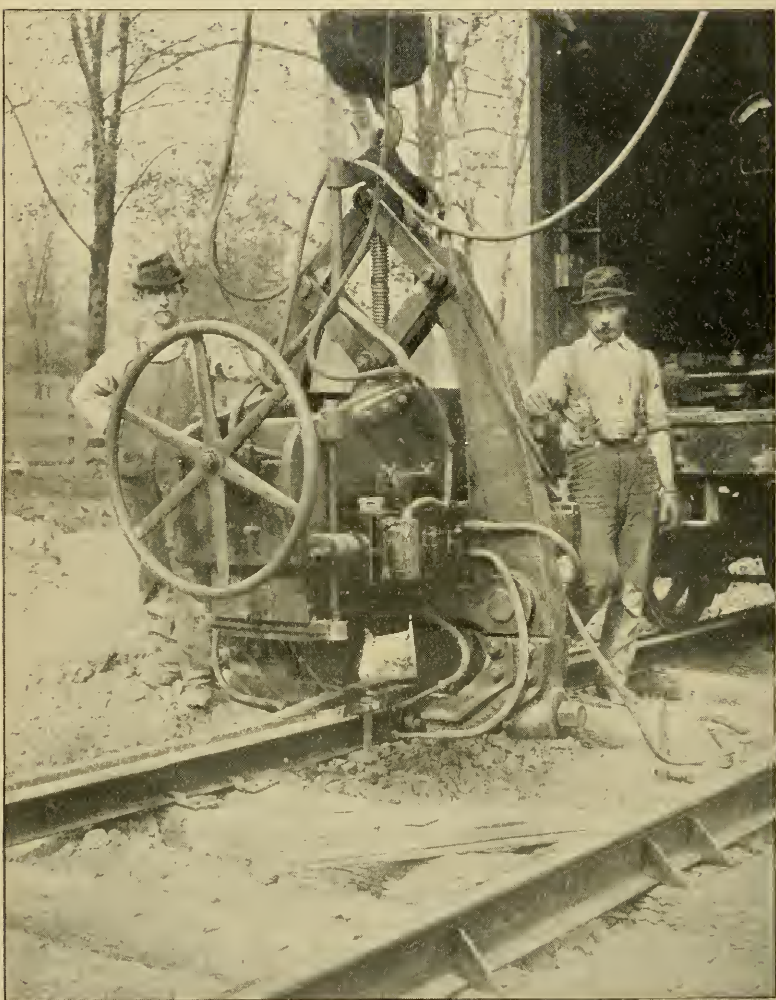

Fig. 3.

the contact clamps screwed down upon them. The circuit through the secondary winding of the welder being thus completed through the lugs, the switch of the welding machine is closed and the iron core of the reaction coil slowly raised. Almost instantly a dark, ruddy color

appears in the lugs which gradually brightens until the welding heat is reached. A quick turn of the screw which operates the toggle-joint brings the lugs firmly up against the rail and forces the plastic steel into the joint between the ends of the rails. The upper lugs are quickly

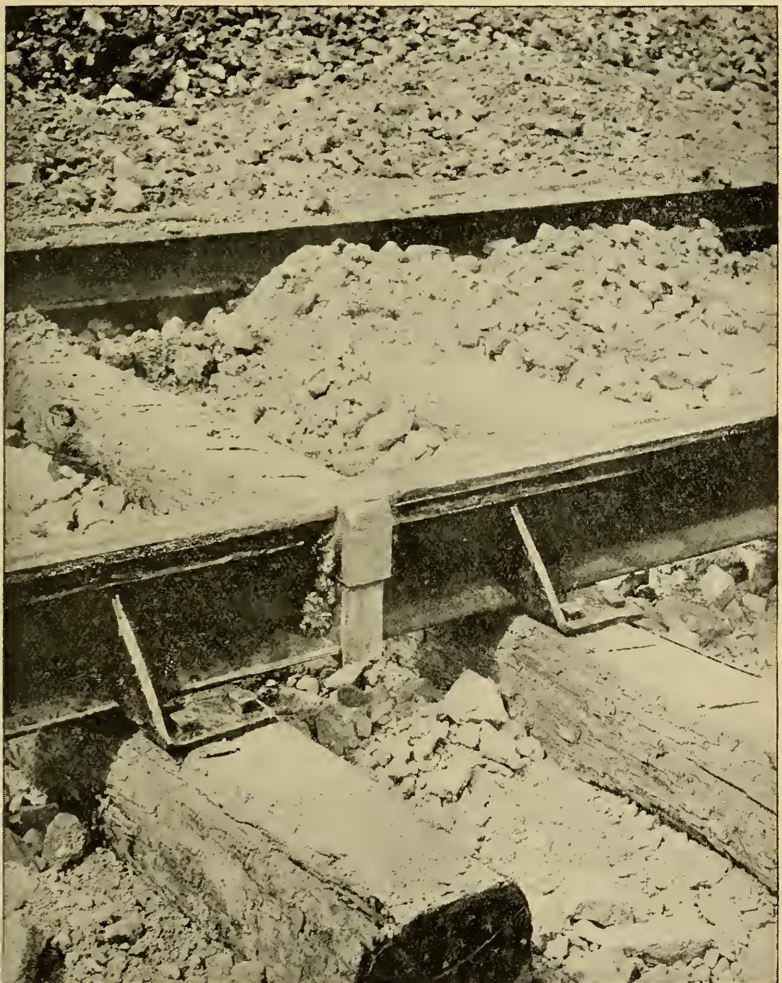

FIG. 4.

inserted, the contacts screwed down upon them and the welding performed in the same manner as in the case of the lower ones. A piece of carbon which has been placed on top of the rail before this operation, keeps this surface smooth and at the same time carbonizes and

hardens the rail at this point. As has been stated, from one to two minutes are consumed in making each weld, but the greater portion of the time is taken up in preparing the joints, moving the machine and setting up the welder. While in St. Louis, the machine completed thirty to fifty joints per day of ten hours.

Since this work has been done, the Johnson Company has built two more welding machines in which some improvements have been made. Instead of placing both the rotary transformer and the welding machine in one car, they are now put in separate cars connected electrically by cables. This makes the machine easier to handle, and distributes the weight over a greater distance on the track. A hydraulic jack has also been substituted for the toggle-joint used in forcing the lugs against the rails. The electric welding done by the Johnson Company in Brooklyn, after leaving St. Louis, was on nine-inch rail laid in paved streets. The track-work was entirely completed and paved up before any welding was done. When the machine arrived, the paving was taken up where necessary and the joints welded, leaving every third joint open. This was done in order to allow the rails to expand under the heat produced in welding. At night the welder was taken over the same track and this third joint welded.

CAST WELDING.

As soon as the fact was demonstrated that a continuous rail buried in the ground was a possibility, other methods besides the electric welding of the joints were proposed. The particular one which will be described here is what is known as the "cast-welding" process, and is being exploited by the Falk Manufacturing Co., of Milwaukee. This, to briefly describe it, consists of clasping the ends of the rails for about eight inches on each side of the joint by means of a mold, and then pouring the mold full of molten iron. The iron solidifies on the rails around the joints and makes a partial union with it.

In order to compare the two methods, the St. Louis Railroad Co., in the fall of 1894, had three miles of track in the southern part of the city connected by the cast-welded process. As the furnace was not ready at the time the rails were laid, the track-work was finished and the trench filled in, leaving the joints temporarily connected by fish-plates. Some three months later, when the furnace arrived, the macadam around the joints was dug up, the fish-plates removed and the rails united by means of the cast-joint. The track was laid in July and August and the rails were welded in October and November. No cars were operated over this track during the winter of 1894-95, but at present the cars of the Southwestern Railway are running regularly over this route.

On account of the excellent record made by this track during last winter, the officers of the Citizens' Railway Co. of this city decided, in relaying the old cable track, to use the cast-welded joint. As many new problems in street railway track construction have arisen during the progress of this work, a brief description of some of the methods employed may not prove uninteresting.

The Citizens' Railway, as all of you are aware, was built as a cable road nine years ago. The original cable track consisted of 9¾ miles of single track, and was laid with 4-inch, 52-pound Johnson girder-rail, which was the heaviest section rolled at that time. The rail was supported on cast-iron yokes, 4 feet apart, and imbedded in concrete. Last fall it was decided to operate the road by electricity, and on the 1st of January the cable power-house was shut down and the electric cars started. The rail adopted for the new track was 7-inch, 85-pound Johnson girder, to be delivered in lengths of 60 feet. Two special trussed wagons with wheel-bases of 45 feet were designed and built for the hauling of these rails. The curves were made of 6-inch, 97-pound girder rail, and all curves of less than 400 feet radius were designed with a spiral easement on each end, and were double guarded. Curves of 400 to 1,200 feet radius have a guard rail on the inside only, while those of still greater radius are sprung from the straight rails. As the new rail was three inches deeper than the old, it was impossible to lay it on the old yokes even if it had been advisable to do so. The ties are laid two feet between centers, and in order to make room for them and the 7-inch rail, it was necessary to take out about twelve inches of the solid concrete in which the yokes were imbedded, as well as to break off the yokes at this point. How to do this in the quickest and most economical manner possible was a problem. As it was necessary to abandon a portion of the road during construction, and as this line has a large passenger travel to take care of, speed in reconstruction was of the utmost importance. After quite a little experimenting, the plan of blasting out the concrete with dynamite was adopted. Two holes are drilled between each pair of yokes on each side of the track by means of a portable steam drill. An Ingersoll-Sergeant drill is used, and the steam is obtained from a 6-horse-power boiler placed in a car on the old track. Connection is made from the boiler to the drill by means of a steam hose. The holes are drilled as nearly as possible directly over the center of the block of concrete and are seven inches deep. The drill is operated from 5 A.M. to 9 P.M., by two shifts of men. The number of holes drilled per day varies from 300 to 700, according to the nature of the concrete. Each hole is loaded with one-tenth pound of 40° Ætna dynamite. Common sand is used for tamping, and from eight to twelve holes are fired at once by means of a magneto. In order to

prevent all danger from flying particles, an old car especially prepared for this purpose is placed over the holes before shooting. This car has been strongly braced and floored with ties, and is provided with heavy sideboards which are lowered before firing, thus forming a completely closed space over the charge. Blasting with this outfit has been done in the narrowest streets in the heart of the city, and up to this date no accident of any kind has occurred. Considerable experimenting was done in order to find out how deep to drill the holes and how much dynamite to use. The quantity adopted will just shatter the top of the concrete so that it may be picked out in large pieces, leaving the con-

Fig. 5.

crete unbroken twelve inches below the surface, thus affording a solid and substantial foundation for the ties. The bottom of the conduit is filled with fine, broken concrete, washed in and thoroughly rammed before the ties are laid in the trench. Having prepared the road-bed in this manner, there remains beneath the ties a solid block of unbroken concrete of the width of the track and over two feet in thickness.

After excavating the trench the track is laid, joined together temporarily by fish-plates, tamped, lined, surfaced and completely finished in every particular before the joints are cast. The apparatus

for casting the joints consists of a cupola furnace mounted on a heavy truck. The cupola is two feet in diameter, brick lined, and the blast is furnished by a No. 5 Sturtevant blower, driven at 1,800 revolutions per minute, by a 5-horse-power motor, which receives its current from the trolley. The cupola is operated as is usual in a foundry, and the iron used is one-half best soft gray pig and one-half selected scrap. The scrap consists of old gear wheels, man-hole covers and frames, an abundance of which are found in the scrap heap of the railway. The furnace works very rapidly, and in twenty minutes after the blast is turned on the iron is ready to pour. It may then be tapped as long as the charging is continued at the top. As the machine

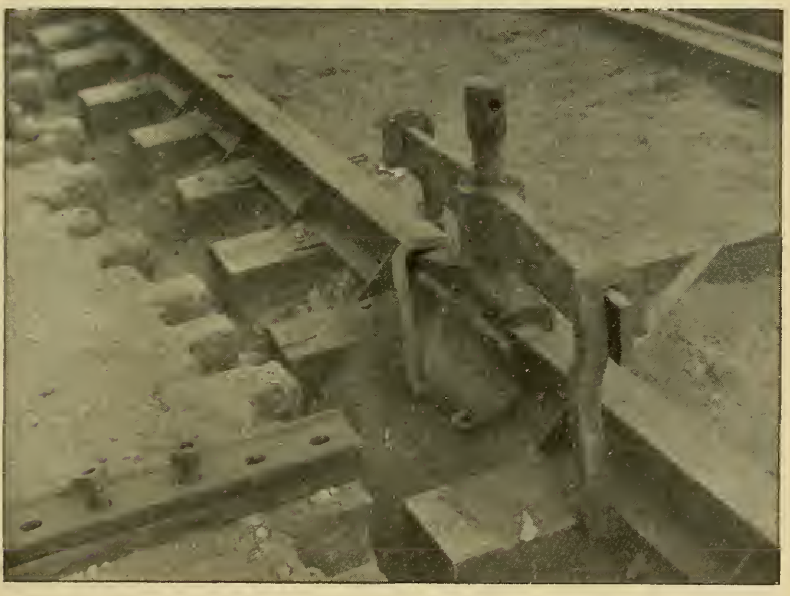

Fig. 6.

has been operated on the Citizens' Railway about 1,200 feet of the track has been prepared, and all the joints molded in one heat. As many as 72 joints have been poured at one melting, and it is probable that 90 or 100 could be made before shutting down the furnace to renew the lining.

The preparation of the joint for casting is as follows: The fish-plates are first taken off and the rail-ends for about eight inches back polished with garnet paper. If there is any opening between the rails it is closed by shims. The molds, consisting of two castings made to fit the rail, are then placed about the joint and clamped in position. A

heavy clamp is placed on top of the rail and screwed up as tightly as possible, to hold the joint immovable while being poured. This clamp is left on the rail until the casting has cooled. Preparatory to the pouring, the molds are lined with a mixture of linseed oil and plumbago and heated to drive out any moisture in them or on the rail. The pouring operation is very simple. The melted iron is run from the cupola into a ladle and then slowly poured into the mold. This final operation is very quickly performed, as it usually takes only about three hours to pour forty joints. The casting weighs 137 pounds and extends back on the rail seven inches, taking in two of the bolt holes in the ends of the rails. In this way four bolts are cast through the rail. It is

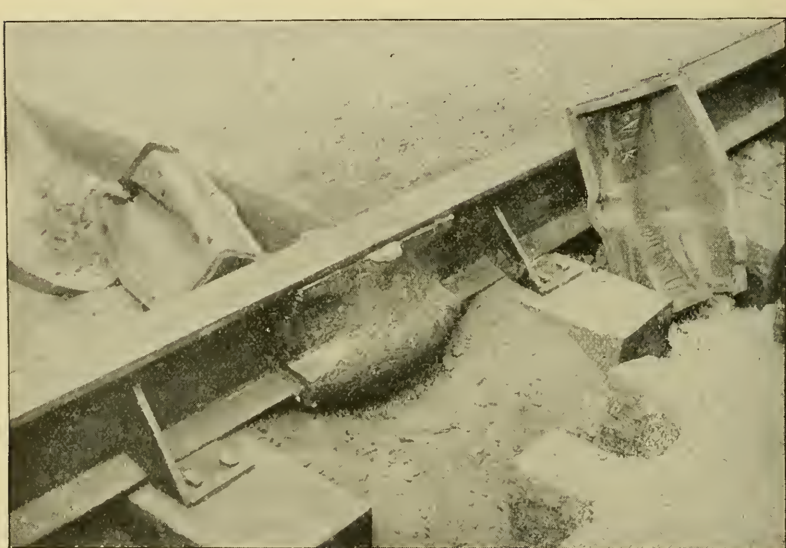

Fig. 7.

undoubtedly the case that a sort of welding action takes place between the iron and the steel rail, as on examination of a joint sawed in two it will be difficult to tell the exact junction of the iron and steel.

RESULTS OF EXPERIMENTS.

Having described the modes of applying these two processes, let us see what they have done in actual operation. The Baden Road, constructed in the spring of 1894, which had its rail-ends connected by the electric method, had in all 2,203 joints, and of these 72, or 3.27 per cent., have broken. Thirty-seven broke during the cold weather of the first part of the winter, and these were repaired by the cast-welding method.

During a later cold snap thirty-five more were broken. These have not yet been repaired. During the heat of the summer no trouble whatever was experienced with alignment of the track. From the Weather Bureau reports the average temperature, while the construction was in progress, was 63 degrees, ranging from 14 degrees as a minimum to 99 degrees as a maximum. During the last winter the lowest temperature was 12 degrees below zero and the hottest day in the summer was 100 degrees, making the range of temperature through which the track has passed 112 degrees, or a maximum deviation from the average welding temperature of 75 degrees. Several of the joints on breaking opened nearly two inches, but in many the opening was so small as barely to be perceptible, the average opening being about one-quarter of an inch. During the warm weather of this summer the openings were diminished slightly, but the joints have never completely closed. Every joint which has broken has shown itself to be an imperfect weld. There has never yet been an instance of a good weld breaking. In all cases, the rail-ends have simply pulled apart, the lugs sticking to that rail which held them tightest. In a few instances small pieces of rail pulled off with the lugs, but in no cases have the rails themselves broken and we have never had a joint to break which looked as if it had ever been really welded. There are several reasons for this. On account of the great distance from the power-house, the voltage was necessarily low while the weld was being made. The work at that time was new and not very well understood, and the workmen who had the machine in charge were often careless and hurried. The result of this experiment is far from being discouraging, and the officers of the railroad company are satisfied that with the additional knowledge we now possess, and with the improvements which have been made in the welding machine, by which a fairly constant voltage is maintained while the welding is in progress, that it is possible to construct a track by this method with an insignificant trouble from breakage.

In regard to experiments elsewhere, Mr. C. W. Wason, Electrical Engineer of the Cleveland Electric Railway Company, has been kind enough to furnish information as to the results obtained in Cleveland. During the summer of 1894, 3,400 joints were made electrically, two-thirds of which were on 56-pound rail and the remainder on 90-pound rail. Of this number, the total breakage during last winter was six, four of them being on 56-pound rail and the remainder on 90-pound rail. The percentage of breakage was 0.18 per cent., which is a much better record than that made in St. Louis. All the joints which broke showed themselves to be imperfectly welded. Mr. Wason expresses himself as highly in favor of the electric method of welding, and states that the breaks and rough joints on his track were due to carelessness on the part of the workmen operating the machine.

The cast-welded track of the Southwestern Railway on Chippewa Street was welded during the months of October and November of the same year. The average temperature while this work was in progress was 51 degrees, with a maximum of 84 degrees and a minimum of 18 degrees. There were 744 joints in all, and during the winter only three, or 0.43 per cent., broke. As stated in the case of electric-welded track, no deviation whatever has been perceived in the alignment. Since this track was laid, the temperature has ranged from 100 degrees as a maximum to 12 degrees below zero as a minimum, a range of 112 degrees and a maximum deviation of 63 degrees from the welding temperature.

The Falk Manufacturing Company, who are making the cast joint, have this summer operated in Chicago, St. Paul, Minneapolis and Newark, besides the work done in St. Louis. In Chicago, for the Chicago City Railway, 11,903 joints were made on 4½- and 7-inch rail, and for the West Chicago Street Railway Company, 8,867 joints were made. In St. Paul, Minneapolis and Newark, work has recently begun, and up to the present time about 2,000 joints have been made in each place. The results so far have been very satisfactory both to the railroad companies and to the contractors.

It seems difficult to those accustomed to steam-railroad tracks to reconcile themselves to the use of a continuous rail. They instinctively call to mind certain experiences they have had with rails creeping and getting out of place on account of temperature variations. It must be remembered, however, that street railway tracks differ in one very important particular from those of the steam railways, that is in having a road-bed firmly packed about the rail. The perimeter of a 7-inch rail is 29 inches, of which only 6½, or 22.4 per cent., is exposed to the air, while the remaining 67.6 per cent. is covered up and firmly gripped by the road-bed. No one can understand how firm this grip is, who has not seen a rail which has lain in a macadam street several years taken up, when the whole buried surface of the rail is found to be covered with a hard cement composed of stones and mud, requiring considerable work with a pick to remove. There is a great tendency on the part of the rail to change its length with the temperature variations, but there is also the ability of the road-bed to hold it in place.

CALCULATION OF STRAINS.

The strain on rails due to the variations of temperature, may be estimated as follows. Assuming a coefficient of expansion for steel of 0.0000065, and multiplying this by 75, which is a liberal figure for the number of degrees of maximum deviation from the welding temperature, we get 0.000487, which is that part of its length which a rail

would expand, due to a rise of 75 degrees, or contract, due to a fall of 75 degrees in temperature. A steel bar will expand 0.00003 of its length, due to a load of 1,000 pounds per square inch. Dividing the estimated expansion by this figure, we get for the strain, 16,200 pounds per square inch. As the rail is $8\frac{1}{2}$ inches in cross-section, the total pull, due to a fall of 75 degrees in temperature, is 137,700 pounds.

As 40,000 pounds per square inch is a safe value for the elastic limit of steel, it can readily be seen that, in this climate at least, the elastic limit will never be reached ; and this means that these expansions and contractions may go on indefinitely, and as long as the joints remain unbroken, no harm will be done to the rail, for it is a well-proven fact that stresses within the elastic limit work no harm.

Assuming 80,000 pounds per square inch as the ultimate strength of steel, we see that, so far as the strength of the rails themselves is concerned, we have a factor of safety of five.

An interesting calculation may be made, showing the friction with which the rail is held by the road-bed. Taking the figures for the contraction of the rail due to a fall of 75 degrees in temperature, each rail of the Baden track should have contracted 8 feet 6 inches. As a matter of fact, when the joints broke, the openings in none of these exceeded 2 inches, and the combined openings of one rail the length of the road did not exceed 6 inches. This would seem to show that the pull which broke the joint was not a transmitted, cumulative effort, extending all along the line, but was more the result of a local strain, not extending for a great distance on either side of the joint. Reasoning from the same data, it would appear that the strain at other points along the track has not been relieved, and that the joints at these other places have shown themselves strong enough to endure the pull.

The strength of the cast-iron joint may be shown to be fully equal to the strength of the rail. The area of its cross-section at the joint is 61.6 square inches. In order to make a perfectly safe estimate, let us assume that its cross-section is reduced 25 per cent., or to 45 square inches by blow-holes and imperfections. Taking for the tensile strength of cast-iron 18,000 pounds per square inch, we have as the ultimate strength of the joint 810,000 pounds, which is largely in excess of the strength of the rail.

COMPARISON OF METHODS.

The two methods just described are the only processes of actually welding rails yet put into operation. The electric welding is scientifically a beautiful process, and when skillfully done, we have no hesitation in saying that the joint is stronger than the rail itself. It has the disadvantage, however, of requiring considerable care and intelligence

to operate it, qualifications which are sometimes difficult to find in workmen. It is also impossible to tell, simply by looking at a joint, whether or not it is really welded. On ordinary railway circuits when the voltage fluctuates continually, it is difficult to operate the process successfully. This, however, it is proposed to remedy by using a storage battery, which takes current from the line when the welding machine is idle, but which is thrown into parallel with the line, and assists in maintaining the voltage while the welding is in progress. The welding machine, with its accessories, is exceedingly heavy and cumbersome, and difficult to move from place to place where track is not already laid. The great expense of an outfit prohibits almost any railroad company owning one, and this complicates the question of repairs, for, if the machine is gone and some of the joints break, how are they to be repaired?

Without wishing to make any invidious comparisons, it would be well to call attention to some of the advantages which the cast-welding process possesses. The first is the relative simplicity and cheapness of the apparatus employed, and the ease with which men may be procured who are used to this kind of work and capable of doing it well. The machine is not very heavy, it does not run on the track and can be transported easily and quickly from place to place. While as yet no difficulties have developed, the weak points of the process would seem to be: first, that the joint is a casting, subject to blowholes, chilling, imperfections and all the ills of a casting, any one of which might greatly impair its tensile strength; and second, the fact that the steel-rail and the cast-iron joint possess different coefficients of expansion, and that, under variations in temperature, internal strains might arise in the joint itself, which might finally result in its rupture. As has already been stated, however, no troubles of this kind have as yet developed, and these are merely considerations which suggest themselves in the examination of the process.

The cost of either of these methods is not greatly in excess of the old fish-plate method, but even if it was, the advantages gained by the abolition of joints would be of such value that no progressive railroad man would hesitate on that account. If either method will remedy for all time trouble with joints, the cost of repairs to the track, after being down a few years if laid with fish-plates, would soon pay the extra first cost, without considering the prolonged life of the rolling stock and the prestige given to the road on account of its smooth riding track. If joints are abolished, the life of a track, instead of being limited by the life of the joints, will be the life of the rail itself, and this will far outweigh any considerations as to the cost of making the joints.

An additional advantage which should be mentioned is that any

form of welding obviates the necessity of bonding the joints of electric roads. Tests which have been made on welded joints show that the electric conductivity of the joint is as great as that of the rail itself. Assuming the conductivity of steel to be one-seventh that of copper, an 85-pound steel rail would have a carrying capacity equal to a copper bar 1.2 square inches in section, or, as feed-wire is usually rated, of 1,500,000 circular mils. A double track, consisting of four of these rails, would thus have a conductivity equal to 6,000,000 circular mils. This is largely in excess of the feeder section of any one line of railway in St. Louis. For instance, the combined section of the feeders which run to the Citizens' line, which was calculated for 60 cars, allowing a drop of 50 volts at full load, is 3,200,000 circular mils. To one who is engaged in the actual operation of street railways this means a great deal. Given a track with a conductivity equal to that just cited, it is necessary only to establish a low resistance connection between the rails and the buss-bar in the power-house, when all the troubles due to a low voltage along the line, and all the dangers of electrolysis would be a thing of the past.

It is not to be supposed that the millennium in track construction has already been reached, but what has been demonstrated is this: first, that the use of a continuous rail for street railway practice is feasible; and second, that it is possible to make joints of sufficient strength to stand changes of temperature. Whether new difficulties will develop remains for the future to show, but let us hope that those of us who have placed our faith in rail-welding will not share the fate of Jules Verne's armor-maker, who planned, mixed, forged and tempered his best, only to see the triumph of his skill shot to pieces by the latest gun of his hated rival.

A STUDY OF THE HEATING AND VENTILATING PLANTS IN THE SUFFOLK COUNTY COURT HOUSE AND THE MASSACHUSETTS STATE HOUSE, BOSTON.

By Percy N. Kenway, Member of the Boston Society of Civil Engineers.

[Read before the Society, September 18, 1895.*]

These two buildings are so nearly alike as regards size, exposure and conditions of use, that a study of their heating and ventilating equipments and some of the results obtained, will, I hope, prove not uninteresting.

But while the buildings are so nearly similar, the heating plants differ from each other very radically and at very many points, both in general design and in detail; in fact, there is hardly a single feature which is common to both.

In each case the selected engineer was in consultation with the architect while the building plans were being prepared, and his suggestions were followed wherever practicable, though in the case of the Court House some progress had been made on the foundations before such consultation, so that the engineers were at a disadvantage. In both buildings the uses to which the different rooms were originally assigned were in some instances changed, during or after construction.

I will first call your attention to the ground plans of the two buildings which are shown in outline, Figs. 1 and 2, on the same scale, and from which you will readily see that the area covered by each of the buildings is somewhat alike. The State House, however, is actu-

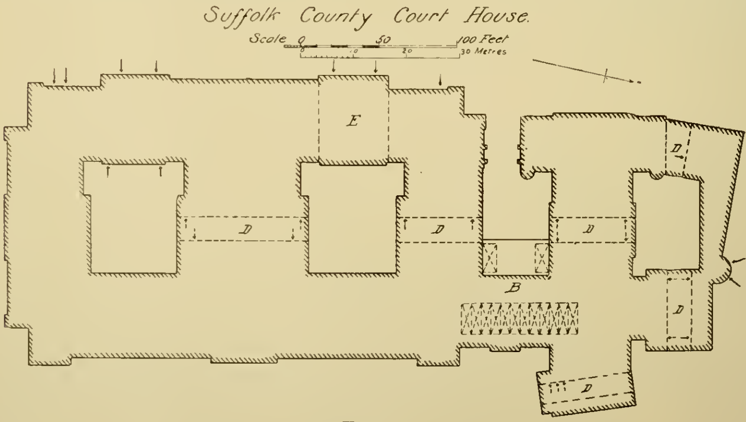

Fig. 1.

* Manuscript received October 31, 1895.—*Secretary, Ass'n of Eng. Socs.*

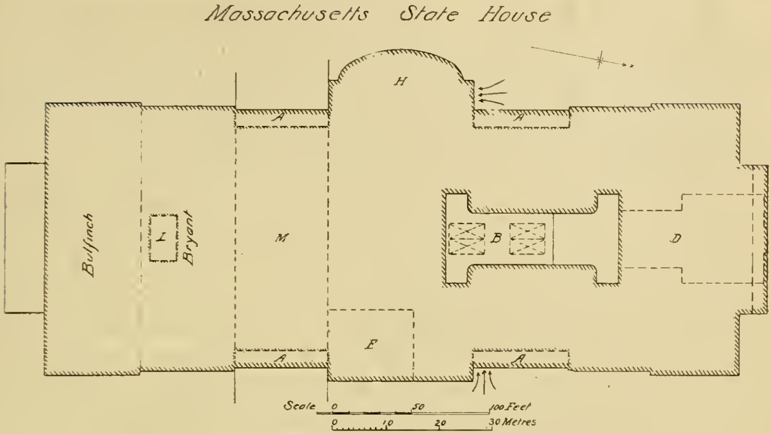

FIG. 2.

ally the larger of the two, careful computation giving the figures in Table I.

TABLE I.

	Court House.	State House without Bulfinch Portion.
Cubic capacity	5,500,000 cubic feet,	6,200,000 cubic feet.
Area covered	65,300 square feet,	67,000 square feet.
Heating surface—direct	35,800 "	15,000 "
Heating surface—indirect . . .	67,000 "	9,560 "
Total heating surface	102,800 "	24,560 "
Cost of building	$2,700,000	$3,000,000
Cost of apparatus	$122,000	$112,000 *

* This includes $6,000 for temporary apparatus for drying the building, and $4,800 for air filters.

For the purpose of this paper we will leave out the Bulfinch portion of the State House, shown at the extreme left of the plan. This is the original building, erected in 1798, the proposed destruction of which has recently brought out such strong protests from many good citizens of Boston. A steam heating plant was installed in this building in 1867, and has since been modified—the original fan for the ventilation of the House and Senate Chamber being replaced by one of more modern type about fifteen years ago.

The Bryant addition, on the north side of the Bulfinch building, was built in 1855, and has now been pulled down and is being rebuilt in conformity with the design of the "Extension." Mount Vernon Street runs under the portion marked M, which, in consequence, has no basement or first floor.

The wing at the right, on the Court House plan, is the Municipal Building, and contains the City Prison and the Criminal Court rooms. The remainder is the County building, devoted to Court rooms, rooms for judges, lawyers and juries, and the Law Library, which occupies nearly the whole of the front of the building on the third floor.

The heating and ventilation of the Court House is accomplished by a hot-water apparatus, operating without pressure except that due to the head of water in the system. The boilers are placed below the lowest radiating surface, special excavation (which on account of the foundations being already in place, was very costly) having been made for this purpose. *B* on the plan indicates the boiler room. The water being heated in the boilers to a temperature varying according to the weather, from 80 to 180 degrees, flows through the supply mains and their many branches, rising till it reaches the various radiators, in which it is cooled, and then flows back through the return pipes into the boilers again—without the intervention of any traps, tanks or pumps—arriving at a temperature averaging 15 degrees cooler than when it began its journey. The usual expansion tank is provided at the top of the building, and the water level in this tank is maintained automatically. The air-vents of all the indirect radiators are connected to two 1½-inch mains, which are run to the top of the building and have a free discharge. The direct radiators are provided with ordinary air cocks

The rooms are warmed partly by passing the air supplied to them through large return bend-coils of 3-inch cast-iron pipe placed in brick chambers at the base of the several flues, and partly by horizontal wrought-iron tube radiators located in the window recesses.

Ventilation is effected without the use of any moving machinery. The tunnels or corridors in the sub-basement which contain the large hot-water pipes serve also as main fresh-air ducts to those rooms which can be reached from them. The Court rooms have, as a rule, independent fresh-air inlets.

The air inlets to the rooms are, in most cases, on the warm or inner side, and are placed at the floor. All the Court rooms, however, have two opposite exposed sides, and in these cases there is an air inlet at each corner on one exposed side, and a corresponding outlet flue on each corner on the opposite side (as shown in Fig. 6). The outlet flues have registers both at the ceiling and at the floor. With this arrangement of air inlet and with no means for diffusing the air as it enters, it is not surprising that when weather conditions are favorable, and the volume of entering air large and its velocity consequently high, drafts are complained of by persons sitting near the supply registers. To avoid these, screens or baffling plates have, in some cases, been provided, and

in some cases the inlets have been raised a few feet above the floor. The efficiency of the air circulation in a room so arranged is evidently open to grave suspicion, for it is obvious that as regards the two exposed sides it cannot possibly be symmetrical. The entering air, being warmer than the air of the room, a large proportion of it—especially where the screens are used—will rise immediately to the ceiling and then gradually

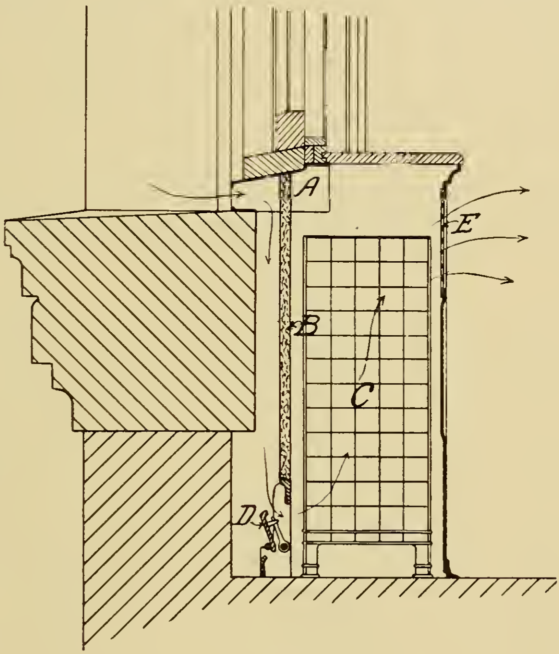

Fig. 3.

find its way down the cooling surface of the windows towards the floor. That portion of it which flows down on the side where the inlets are placed, will have to cross the room to the outlets at a low level and will do useful work, but that which comes down on the other side can reach the outlets almost without working its passage, and except for the foul air at the ceiling—which doubtless it does help to dilute and displace—it would be almost as pure when it left the room as when it entered it.

The temperature in the rooms is regulated very approximately by the temperature of the water in the main supply pipe—a thermometer being placed in this pipe for the guidance of the engineer, who varies the condition of his fires and the number of boilers used, according to the outside weather. A further regulation in any particular room is effected by operating the valves of the direct radiators under the

windows, or by changing the position of the mixing dampers which are provided for all the Court rooms.

It was prophesied before the apparatus was completed, that a large corps of supernumerary engineers would be needed to regulate with every change in the weather, the many valves and dampers which form a part of the apparatus. This, however, does not prove to be the case; in the Court rooms the mixing dampers are rarely touched except when something of unusual interest is going on, and the room is consequently crowded. Then the adjustment is usually made by one of the two engineers. In the smaller private rooms the radiator valves and cold-air dampers are controlled by the occupants, while in the jury and other rooms—which have no air-supply flues, and are not occupied constantly by the same persons—the valve wheels have, in most cases, been removed as a safeguard, and the temperature of such rooms is dependent on that in the apparatus and on the amount of air admitted behind the radiators.

The ability to approximately regulate the temperature in such a large building from a central source is undoubtedly one of the strongest arguments in favor of a hot-water apparatus as against steam. A range of temperature extending over more than 100 degrees Fahrenheit is at the disposal of the engineer, without in any way straining the apparatus or increasing the pressure, whereas a pressure of about 70 pounds per square inch would be needed in the case of steam to get an additional 100 degrees over the temperature at the boiling point, and such a pressure in a large apparatus, with many thousands of joints and fittings and some miles of piping, would be impracticable and even dangerous.

There are in the Court House about 220 occupied rooms, including the large Law Library and some twenty other very large rooms used as court rooms or rooms for hearings, but not counting toilet rooms. The Law Library has a cubic capacity of about 132,000 feet, and the other large rooms average nearly 40,000 feet each. About twenty of these two hundred rooms are used for unimportant purposes and have direct radiation only, without air supply. Ninety of them have direct radiators in the window recesses, enclosed in cast-iron casings and arranged to warm air taken from the outside through cast-iron subsills, as shown in Fig. 3. *A* is the subsill; *B* an apron of 1 inch hair felt, cased in galvanized iron, extending across the window recess; *C* is the radiator; *D* a damper for admitting air behind the radiator, and *E* the grating through which the air escapes into the room. The dampers are under the control of the occupants of the rooms, and, as a matter of fact, in cold weather most of them are closed, the occupants preferring to have them so. These rooms all have vent-flue connections, but no air supply other than that admitted through the dampers *D*, so that, with these dampers

closed, the ventilation cannot be very excellent. However, in most of these rooms the number of occupants is small and a large supply of air is not needed.

The remaining one hundred and ten rooms have both air supply and vent-flue connections, in addition to direct radiators in the window recesses. These radiators, however, have no subsill air supply, but are simply enclosed in cast-iron screen work, with gratings at the top and bottom for the circulation of air.

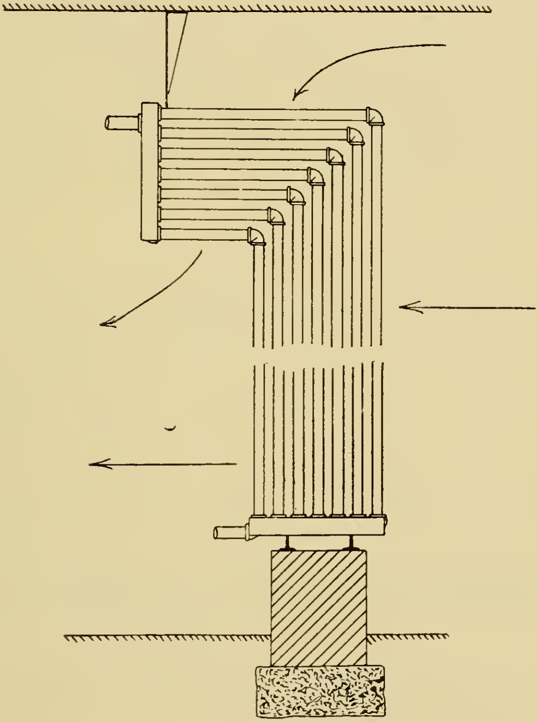

FIG. 4.

The corridors and hallways are warmed by indirect radiation, without air supply from the outside. An air connection is made from the floor of the hall, or corridor, to the underside of indirect stack, and another connection from the top of the stack to the floor again, or to a register in the wall above the floor. In this way these spaces are warmed by circulating the air contained in them through the indirect radiators.

The amount of air supplied with this, as with any gravity ventilating apparatus, is dependent, first, on the difference between the inside and outside temperatures; second, on the direction and force of the wind; third, on the barometric pressure; fourth, on the amount of heat

used in the aspirating coils in the vent shafts, and fifth, on the area height and form of the supply and vent flues and their freedom from obstructions and changes of direction. From this it will be seen that the air supply in this building is not likely to be constant, but must, of necessity, vary from day to day with the outside weather conditions. The severest test for such an apparatus is a spring or autumn day when the barometer is low, the air still and the temperature a few degrees too cool for open windows. If the amount of air supplied on such a day is up to the standard, then of course it would be theoretically possible to keep the supply constant, and to have neither more nor less air than is needed at any time; but as this would entail, in the case of the Court House, the very frequent, perhaps hourly, manipulation of seventy-four cold-air dampers, it would hardly be practicable, and as a matter of fact it is not attempted, although the dampers are used to check the flow of air to the rooms when it becomes too generous under favorable weather conditions.

Turning now to the State House, we find there a steam apparatus throughout. A pressure of 100 pounds per square inch is carried on the boilers for the purpose of running the engines in connection with the electric lighting plant, but only from two to ten pounds is used in the heating apparatus. The boiler room is located in the courtyard of the extension—as shown at *B* on the plan—and its floor is about two feet below the level of the sub-basement. It is a one-story structure, the roof being largely of glass, making it an exceptionally light room.

The different pressures carried and the high pressure needed for the engines made a gravity apparatus impracticable in this case, and consequently the water of condensation from all the direct radiators and from the main coils—with the exception of the exhaust steam sections—is returned to the boilers through a series of traps, tanks and pumps. The rooms here, as in the Court House, are warmed partly by the air supply and partly by direct radiation; but in this case the indirect radiation, instead of being divided up and placed at the bases of the several flues, is massed in large stacks near the main air inlets. The two sets of stacks, through which passes all the air supplied to the extension (the whole building except the Bulfinch and Bryant portions), are built of 1-inch wrought-iron pipe, and are made up of a series of miter coils set up on end and connected together in sections. The arrangement will be better understood by referring to Fig. 4, which shows one of the coils and its relation to the floor and ceiling. The largest stack contains ninety of these coils, connected together in groups of ten, each group having separate controlling valves.

Ventilation is effected by fans driven by electric motors, and for this purpose the extension is divided into two sections, the Bulfinch

and Bryant portions together making a third, so that there are three supply fans and three sets of main coils. The general method of ventilation can be understood from a description of the apparatus on the west side, which is the more interesting as it supplies air to the House of Representatives. The air inlet is on the west side, and is indicated by arrows on the plan. On its way to the fan the air first passes through a series of primary coils, which are designed to heat it to about 40 degrees in zero weather. Between these coils and the fan there is a large chamber in which it was designed to place an air filter; but this has not as yet been constructed. The fan is 12 feet diameter and 14 inches wide

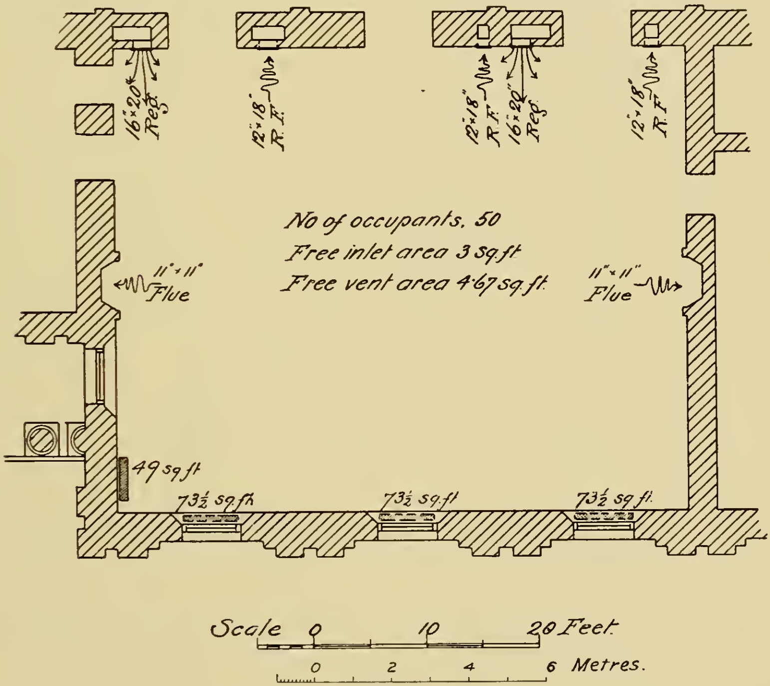

Fig. 5.

at the tip of the blades. It is a cone fan of the Briggs-Meigs type, modified by Prof. Woodbridge, and has proved very efficient and economical of power. The one on the east side is of the same type, but two feet less in diameter, as it has less work to do.

After passing through the fan the air is forced through a secondary coil, and is further heated to about 75 degrees, at which temperature it is distributed through the vertical ducts to the different floors. The total area of the main air supply ducts on this side is 145 square feet, 45 square feet being for the House of Representatives. Horizontal

branches are taken out of the vertical ducts at each floor for the purpose of distributing the air to the rooms. These horizontal ducts are formed by furring down the ceilings of the corridors, so that they are not visible, and by the casual observer would be unsuspected. The air inlets to the rooms are in most cases taken directly out of these corridor ducts, so that they are on the inner side of the rooms and usually something less than three feet below the ceiling. The vent outlets are, in nearly all cases, at the floor, and, wherever practicable, on the warm side, and are furnished with gossamer check valves to prevent down-drafts. No ceiling outlets are provided and the floor outlets have no register valves. Some of the rooms which could not be reached from the corridors have separate air-flues leading up from the sub-basement, and connected to the warm air chamber by galvanized iron piping. In these rooms the air inlets are about eight feet above the floor.

The House of Representatives, the location of which is indicated by the letter *H* on the plan, is elliptical in form, 86 feet long by 70 feet wide and 44 feet high, has a cubic capacity of about 264,000 feet and seats 240 persons on the floor and about 200 in the galleries. On special occasions, when the standing room is occupied, as many as 1,800 persons may be inside the doors at one time. This chamber is treated in a special manner, the conditions being different to those existing in the other rooms. A special vertical air-duct is provided, which has two openings at the base, both connecting with the air-pressure chamber, but one connecting on the inside and the other on the outside of the secondary coil, so that air at 40 or at 75 degrees, or at any intermediate temperature, as required, may be supplied. Mixing dampers, automatically controlled by thermostats, are provided in front of the openings and keep the temperature of this important legislative chamber practically constant, in spite of variations in the weather and in the number of occupants. The air-inlets to this room are differently arranged to those in the other rooms. The desks on the floor and the seats in the galleries are fixtures, and the floors are raised and inclined in such a manner as to give a considerable air space between them and the ceilings below. Into these spaces the air from the vertical duct before mentioned is discharged, so that they become air-pressure chambers. The desks are of special construction and have hollow bases which connect with the air chamber below, and the air finds its way into the room through gratings (backed by coarse haircloth) in these bases and in the risers of the floor, which is stepped. The gallery inlets are somewhat differently arranged, though the same principle of a large and evenly distributed inlet area near the floor and a low velocity of air flow is carried out. The total area of inlet is about 240 square feet for the floor and 200 square feet for the galleries, or one square foot for each regular occupant.

The main vent outlet is at the ceiling, where a free area of about 20 square feet is provided, but there are also 16 square feet of outlet area in the rear walls for the galleries. The ordinary air supply to the House is 900,000 cubic feet per hour, but it has been found quite possible on special occasions to raise it to 1,300,000, and that without causing disagreeable drafts. Samples of air taken at the ceiling ventilator towards the close of the exercises on the occasion of the Governor's inauguration last January, when fully 1,800 persons were inside the

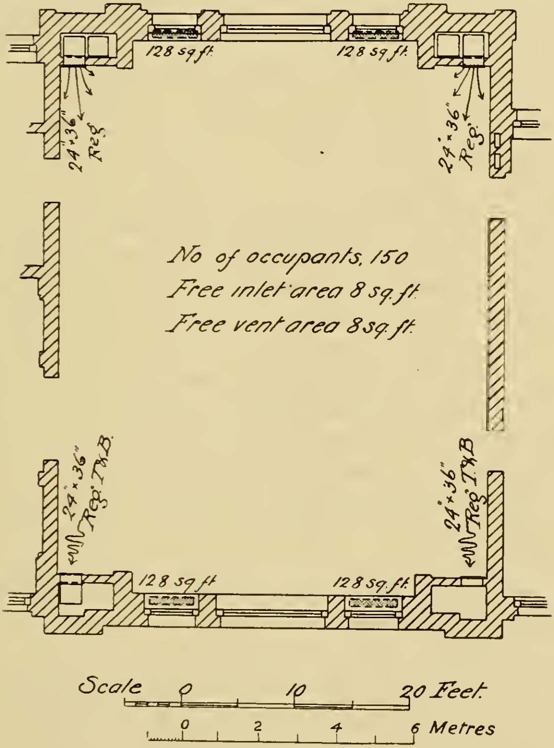

FIG. 6.

doors—more than four times the seating capacity—gave by the Pettenkoffer method 12.1 parts of carbon-dioxide in 10,000—a large proportion under ordinary circumstances, but a very satisfactory showing considering the adverse conditions and the fact that the samples were taken at the point of maximum impurity. It may be mentioned incidentally that a Wolpert air tester, carefully used at the same time and place, gave but 8¼ parts CO_2 in 10,000, indicating an error in the latter instrument of more than 30 per cent. As the Wolpert device is used by the District Police in testing the air in the schoolhouses of this State, this fact has some significance.

The warming of the House is done entirely by the air supply, no direct radiators being used. The temperature of the incoming air, when the room is occupied, rarely exceeds 70 degrees in the coldest weather.

The temperature of the air supply and of the rooms and corridors throughout the building, is automatically controlled and kept constant within one or two degrees by the Johnson Electric System, so long as the weather is cold enough for artificial heat to be required. Thermostats are placed in the main air ducts and control sections of the main coils, and in each of the rooms and in the corridors there are other thermostats controlling the valves on the direct radiators. The mixing dampers above mentioned, which regulate the temperature of the air to the House, are also controlled by the Johnson System. *No valves or dampers are accessible to the ordinary occupants of the building, or need to be operated or thought of by them.*

In the completed building there will be about 200 occupied rooms, including the House of Representatives, the State Library and the Senate Chamber. Of these, 170 will have connection to air supply and vent flues as well as direct radiation. The remaining thirty include such rooms as the restaurant and kitchen, and the Board of Health laboratories on the fifth floor, which have liberal vent connections, but take their air supply from the hallways and corridors; and the stack rooms, on the third floor, through which the air from the State Library passes on its way to the vent outlets. The advantages and economy of such an arrangement are obvious. The large volume of nearly pure air at the top of the building is utilized, and a continuous inward current is insured towards those rooms which might otherwise be centers for the distribution of foul odors throughout the building. Similarly all the toilet rooms, instead of having their own air-supply flues, as is the case in eight of the large toilet rooms in the Court House, take their supply from the corridors through gratings in the lower panels of the doors, and the vent-flues from these rooms are all connected to an exhaust fan which is kept running continuously. Exhaust fans are also provided for the kitchen and restaurant, and for the laboratories, and these are run intermittently as needed. Ventilation in the stack rooms is required principally for the preservation of the books, so that the air from the library, which is usually a very thinly populated room, is entirely pure enough for the purpose, and it would, in fact, be wasteful to use fresh air.

There is a fourth exhaust fan in the State police department in the sub-basement, where confiscated liquors are disposed of. This was not anticipated in the original design, but was found necessary on account of the strong fumes liberated.

All the fans are run by electric motors. Vent-flues, other than

those mentioned above as being connected with fans, are merely carried up above the roof and suitably capped. No aspirating coils are provided or needed.

The total amount of air which the apparatus is capable of supplying to that portion of the building known as the "Extension" is 10,000,000 cubic feet per hour, or say 50 cubic feet per minute to each of 3,300 occupants. Add to this 2,500,000 cubic feet per hour for the Bulfinch and Bryant portions, and we get 12,500,000 cubic feet as the total for the completed building. This amount, it should be noted, is practically independent of outside weather conditions, and is well under the control of the engineer, who can reduce it as may be required. It is, of course, dependent on the fans and motors; if these should become disabled, then the air supply would be very greatly reduced, and with unfavorable weather conditions this building would be worse off than the Court House. But such a contingency is not likely to occur except at long intervals, and even then the stoppage would be of short duration and would not interfere with the use of the building.

We now come to the consideration of some of the details in the two buildings.

In the Court House there are twelve horizontal tubular hot-water boilers of 80 nominal horse-power each, and two steam boilers of the same type of 50 horse-power each, making a total of 1,060 nominal horse-power. The steam boilers are for the elevator pumps and have no connection with the heating apparatus except that the exhaust steam, after passing through a feed-water heater, escapes to aspirating coils in two of the vent-shafts. There is no electric lighting plant in the building. Of the twelve hot-water boilers, eight have been found sufficient in the coldest weather experienced since the apparatus was installed. The firing is done by hand, Cumberland coal being used.

In the State House there are four Babcock & Wilcox boilers of 208 nominal horse-power each, or 832 horse-power in all. These boilers are designed to supply steam to the entire heating apparatus, to the elevator pumps, and to a 5,000 lamp electric lighting plant. Last winter, beginning with January, the entire building—except that portion marked *M*, which was not built—was warmed by steam from these boilers, as was also a large building across the street on the east side known as the Commonwealth building. The electric current was at the same time supplied to 3,500 16-candle-power lamps or their equivalent, and in the coldest weather only three out of the four boilers were used, showing that there is an abundant reserve force to take care of the whole building when completed. Roney mechanical stokers are used for firing. The coal is brought from the bin in a steel car running on a 2-foot track, is weighed and shoveled into hoppers secured to the boiler fronts above the grates.

Special arrangement has been made for the disposal of ashes. Between and below the two pairs of boilers there is a fire-proof chamber with connection to each of the four ash pits; the ashes are dumped into this chamber and do not appear on the floor of the boiler room at all. A mechanical conveyer raises the ashes out of the chamber and deposits them through a chute outside the boiler-room wall, ready to be carted away.

In a hot water apparatus we should naturally expect to find the supply and return pipes of a larger size than those in a corresponding steam apparatus, so here, in the Court House, the main supply pipe or drum is 30-inch internal diameter, with 14-inch connections to twelve boilers. In the State House the largest supply main is 10 inches, with 8-inch connections to four boilers. The return mains in the Court House are the same size as the corresponding supply pipes, the return drum being 30 inches in diameter, whereas the largest return main in the State House is only 3½ inches in diameter.

All pipes in the Court House larger than 5 inches in diameter are of cast iron, flanged. No cast-iron pipes are used in the State House.

In the Court House the supply and return mains are in the sub-basement; the larger pipes run in the fresh-air supply ducts and are covered with hair felt and canvas, an excellent non-conductor for hot-water work, but objectionable from the fact that it has become infested with vermin. Each line of radiators has its separate supply and return riser, so that there are in the building 80 pairs of risers, not counting those which do not reach up to the second floor—160 rising lines in all.

In the State House the supply to the direct radiators is first taken to the top of the building by two 7-inch risers, and is thence distributed to the downward feed pipes by mains running in the roof space and covered with asbestos cement felting. Exclusive of those in the Bulfinch portion, there are 67 of these "droppers" or downward feeders which perform the function of carrying away the water of condensation as well as supplying steam to the radiators, so that no return risers are needed. The average size of these vertical pipes is very nearly the same in both buildings, about 2 inches in diameter. The "droppers" are concealed in slots in the brick walls, which are covered with cast-iron plates. These plates have perforations near the floor and near the ceiling, so that a circulation of air is maintained and the heat utilized. The ordinary pressure carried on the direct radiator system is under 5 pounds per square inch.

The direct radiators used in the Court House are constructed of one-inch pipe screwed into cast-iron headers at one end and into return bends at the other, the bends being tapped left hand. They are practically ordinary pipe radiators set with the pipes horizontal instead of

vertical. This form was adopted partly because of the ease with which such radiators can be made of varying heights, widths and lengths to suit the different window recesses and the amount of surface specified.

The State House radiators are of the H. B. Smith Union pattern for hot water, vertical cast-iron loops connected together at top and bottom. Each radiator has a supply connection at the top and return connection at the bottom, both connecting with the same vertical pipe.

The amount of radiating surface in the Court House is vastly larger than in the State House, notwithstanding that the latter is the larger building and has ample surface to more than meet all the requirements. I am not able to state exactly the area of the exposed window and wall surface in the two buildings, but it is probable that the proportion of such surface to cubic capacity is greater in the Court House than in the State House, and the actual figures might possibly show a surplus for the Court House. Bearing this in mind, and also making liberal allowance for the fact that we are dealing with hot water in one case and with steam in the other, it is still very evident that an extravagant factor of safety was used in designing the Court House apparatus.

For purposes of comparison I have selected a large room in each building, which will, I think, help to bring out this point more clearly. The room in the County building which I have chosen is one of the Court rooms on the second floor on the west side (Fig. 6), and the one in the State Building is on the third floor on the east side, and was originally assigned to the Secretary of State (Fig. 5). Their respective locations are indicated by the letters *E*, *E* on the floor plans. They were chosen with reference to their size and exposure, and by referring to Table II it will be seen that while the rooms vary very little in those particulars, yet the Court Room has 89 per cent. more direct surface and 1,347 per cent. more indirect surface than has the room in the State House. It should be noted, however, that this difference is in part due to the use of hot water without a fan in one case, and steam with a fan in the other, and also to the fact that on account of the larger number of occupants in the Court Room, a larger maximum air supply has been provided for. But even when all this has been taken into consideration, the excess in the Court Room is still very remarkable, and I do not think that "extravagant" is too strong a term to apply to the "factor of safety" there used.

The figure 85 which is given in Table II as the amount of indirect surface for the room in the State House is in the same proportion to the total indirect heating surface on the east side (4,240 square feet), as the amount of air supplied per hour to the room (150,000 cubic feet) is to the total air supply per hour (4,500,000).

TABLE II.

	Court House. Room 22, 2d Floor.	State House. Room 113, 3d Floor.
Floor area, square feet	1,813	2,090
Cubic capacity	28,300	39,700
Glass area	340	260
Exposed wall area	920	994
Glass plus wall	1,260	1,254
H. S. direct	512	270
H. S. indirect	1,230	85

By referring to Table I, it will be seen that much the same proportions are maintained when the two entire buildings are compared. The Court House, with 11 per cent. less cubic capacity, has 318 per cent. more heating surface, and this is without taking into account the large amount of surface in the enormous supply and return mains.

With regard to the coal consumption in the two buildings, I have not found it possible to get data for a fair comparison. The amount used in the Court House from January 1 to June 1, 1895, was 995 tons, and in the State House for the same period, 1,465 tons. But it must be remembered that in the latter building there is a 5000-lamp electric light plant, some portion of which was in operation day and night, and that the Commonwealth Building, the Bulfinch and Bryant portions, and the Extension (except that part over Mt. Vernon Street), were all warmed during this period by steam from the new boilers. Also it should be noted that the north side of the Bryant portion and the south end of the Extension were then outside exposures.

The electric lighting bill for the Court House, covering the period above mentioned, was $3,030, which must be placed against the State House expenses. This is enough to pay for the extra coal used in that building and leave a balance of $300 a month towards the heavier running expenses, but even then we do not get an accurate comparison, as many more lamps are used per hour in the State House, and there are six elevators there against three in the Court House.

The number of employees in the engineer's department is greater in the State House than in the Court House, partly because of the lighting plant, and partly because of the State law which limits the working hours of State employees to eight in twenty-four, a law which does not affect the Court House. There are in the State House three engineers, six firemen, three oilers and two electricians, against two engineers, five firemen and one electrician in the Court House.

The Court House apparatus was designed by Bartlett, Hayward & Co., of Baltimore, and installed by the Samuel I. Pope Co., of Chicago. That in the State House was designed by Prof. S. H. Woodbridge, of the Massachusetts Institution of Technology, and installed by A. B. Franklin, of Boston.

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RECONSTRUCTION OF THE CAR FERRY TRANSFER APRONS AT PORT COSTA AND BENICIA.

BY JOHN B. LEONARD, MEMBER OF THE TECHNICAL SOCIETY OF THE PACIFIC COAST.

[Read before the Society, May 3, 1895.*]

FOR the data upon which I have based my description of the operating machinery, I am indebted to the paper prepared by Mr. A. Brown and read by Mr. Harris before the American Society of Civil Engineers in April, 1890. I also wish to acknowledge many favors tendered to me by Mr. F. Teichman, who, under the supervision of the Engineer of the Maintenance of Way Department of the S. P. R. R., prepared the details for this work.

The steamer "Solano" was built in 1879 for the purpose of transferring a train of cars (48 freight or 24 passenger, with engine) across the straits of Carquinez between Port Costa and Benicia.

The transfer aprons that I will attempt to describe to you are for the purpose of connecting the tracks on the wharves with those on the boat.

The "Solano" having been in service for a period of sixteen years, it became advisable to dock her and make some needed repairs. This opportunity was taken to reconstruct the transfer aprons. It had for some time been apparent to the engineers of the Maintenance of Way

* Manuscript received October 18, 1895.—*Secretary, Ass'n of Eng. Socs.*

Department of the Railroad, that the construction of these transfer aprons was much too light for the present traffic. The increased volume of business and the much heavier rolling stock that is now being used are the reasons for strengthening these aprons.

Fig. 1 shows the general details of the aprons as originally constructed. The apron, as reconstructed, will have practically the same general dimensions as those of the original apron, *i. e.*, 100 feet long by 44½ feet wide, and will carry four tracks similar to those on the boat. The apron will consist of five longitudinal bowstring trusses, and a system of transverse floor beams carrying intermediate track stringers.

One end of the apron is at all times supported by the wharf, and is also hinged at this end. The other end is supported by means of a submerged pontoon and counterweights, but during the operation of loading or unloading, additional support is given by the boat.

The supporting capacity of the pontoon is 95 tons, and of the counterweights 25 tons, making a total supporting capacity of 120 tons. An excess of supporting capacity to the proportion of static load that is carried at the free end, is for the manipulation of this end of the apron. The machinery for doing this will remain the same as in the original construction.

At the first panel point from the free end, the apron will rest on the pontoon. At a distance of 12′ 1¾″ from the free end there will be a transverse bowstring truss, the ends of which will be secured to the counterweights. This transverse bowstring truss will transmit to the longitudinal apron trusses the supporting power of the counterweights. The wire rope which connects the ends of the transverse truss to the counterweight is double and continuous, and passes around equalizing sheaves both at the truss and the counterweight. The pontoon is connected to the apron in such a way as to resist both tensile and compressive stresses.

The power for operating the counterweights is derived from a hydraulic lift. From the top of the box containing the counterpoises, the chain K passes partially around the sheaves l and m, the crosshead T, and is secured at n. From the bottom of the counterweight the chain K' passes similarly around l' and m', and is secured at n'. The water is supplied from the accumulator G, into which it is pumped from the tank R, on the Benicia side, by an electric motor. On the Port Costa side the tank R is situated on top of a hill and is supplied by the local water works. The distribution valve of the lift T, shown in detail on Fig. 1, is so arranged that when the feed is cut off, the ends of the cylinder are connected, so that the piston may move in either direction, the water in the cylinder merely circulating around, thus permitting the end of the apron to rise and fall with the tide or the boat.

The action of the free end of the apron is as follows: the excess of the supporting capacities raises the apron above its bearing in the cockpit of the boat, when such bearings are at the maximum elevation, *i. e.*, the boat is unloaded. The boat comes into the slip to receive or discharge a train. A horizontal motion of the hydraulic lift in the direction of the wharf raises the counterweight, and thus throws an unbalanced weight on the pontoon. This unbalanced weight sinks the pontoon until the trusses of the apron come to their bearing in the cockpit of the boat. The apron is then latched down and the counterweights released. The boat is held up to the apron by means of two mooring rods *M*, which extend the length of the apron, are hinged at *H* and bolted back to the piling as shown. The rods *M* are connected to the boat by means of links and tightening levers. The apron is now free to follow the fluctuations of the boat due to loading and unloading, or the rise and fall of the tide. Upon unlatching the apron the unbalanced weight immediately raises the apron free from its bearings. The object of connecting the crosshead *T* to the bottom of the counterweight is to keep the piston always in a position ready to act at once.

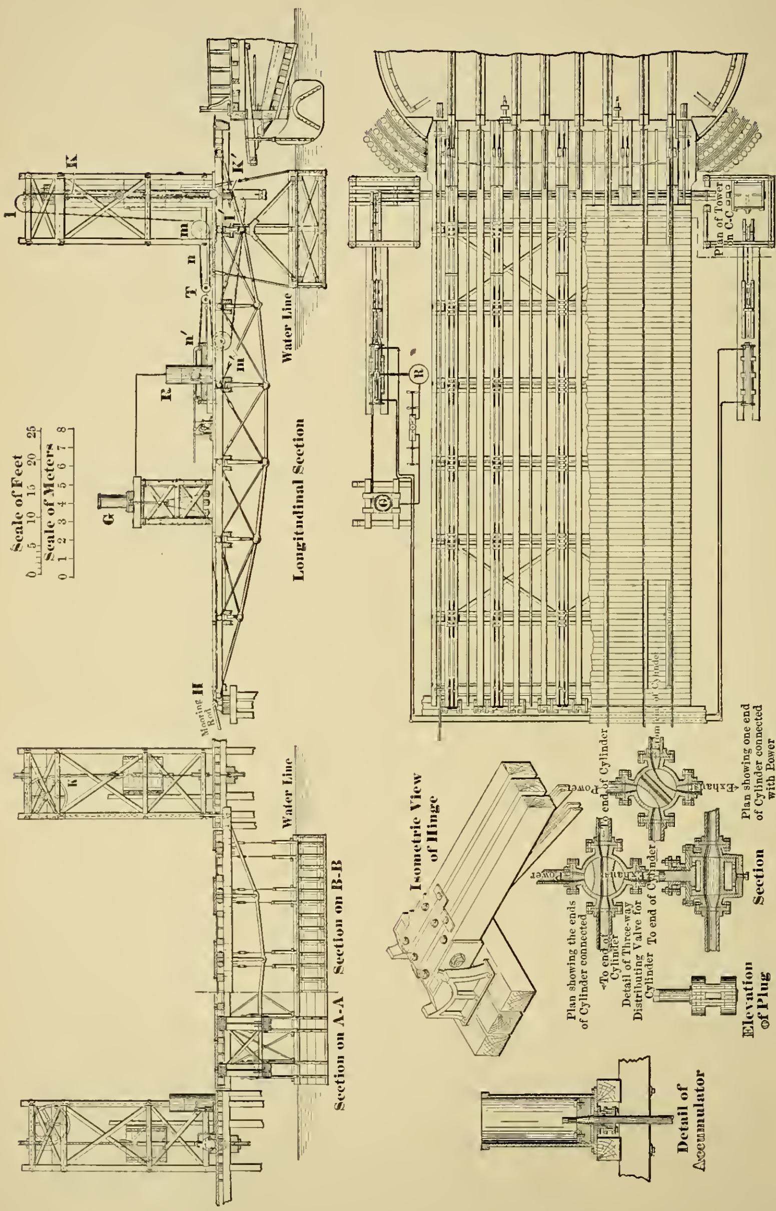
The two outer trusses of the apron will carry the outer rails of the outside tracks on their top chords, while the other rails will be carried by 14 x 16 track stringers which rest on the transverse floor beams.

The trusses are of the pin-connected combination type of construction. Each truss has six panels of 13′ 3″ each, and one 18′ 3″, making 99′ 3″ center to center of end pins, and a depth at their center of 8′ 6½″ center to center of pins. The depth of the trusses was limited by the distance from the base of the rail on the boat to the loaded water line. The form of the trusses is such as to secure very nearly the same maximum stress in each panel under the conditions of maximum loading for such panel.

The trusses are built in duplicate for the sake of economy in the cost of manufacturing and erection. The only places where there is any excess of material are the web systems and bottom chords of the outside trusses. The transverse stresses of the top chords in these trusses, in addition to the logitudinal stress, require about the same sectional areas as are used in the other trusses.

The maximum unit strain in the tension members will be 15,000 pounds per square inch, and this strain will occur only when trains are on adjacent tracks.

The top chords of the trusses are built of three pieces of Oregon pine, 8″ x 16″, and two 15″ steel I-beams, 41 pounds per foot. The 15″ beams are placed one on each side of the timber chords, the timber being framed so as to fit snugly up against the web of the beam. The web members are connected to this chord by means of pins, these pins having bearings



Scale of Feet
0 5 10 15 20 25
Scale of Meters
0 1 2 3 4 5 6 7 8
Longitudinal Section
Water Line
Mooring Rod
Section on A-A
Section on B-B
Water Line
Plan of Tower on C-C
Isometric View of Hinge
Plan showing the ends of Cylinder connected
Detail of Three-way Distributing Valve for Cylinder
Plan showing one end of Cylinder connected with Power
Power
Exhaust
To end of Cylinder
Section
Elevation of Plug
Detail of Accumulator

Fig. 1.

in castings. The castings rest on top of, and are bolted to, the vertical posts, and project up between the leaves of the timber portion of the chord, into which they are framed. The diameter of the pin hole in the timber is such as to make a snug fit, while those of the beams are $\frac{7}{8}''$ larger than the pin. In this way all of the horizontal components of the diagonal web members are transmitted to the timber portion of the chord. At the ends of the trusses the beams are riveted to the castings, and both beams and timbers come to a bearing on the pin. To insure the timber coming to a firm bearing in the castings, iron wedges will be driven in the joints at the ends of the timbers.

The reasons for building the chords in this way are these: First, it was found to be much cheaper than an all iron construction, one item in favor of the cost of this construction being that the most of the cast iron is taken from the old work. The limited time in which to perform the work was a very important factor against an iron truss or girder. An all timber chord could not be used because it packed out too wide horizontally with a 16″ depth, and to increase the depth of the timber sufficiently to permit it to be packed in the horizontal space available, would decrease the depth of the truss, or in extreme cases dip the bottom chord too much into the water.

For proportioning the chord sections the moduli of elasticity of timber is taken at 1,800,000 pounds, and of steel, at 29,000,000 pounds. Since the two materials will resist the stresses in proportion to their rigidities, which from the above moduli are found to be nearly as 16 to 1, the sectional area of the timber to the steel is as 16 to 1, as near as commercial sizes will permit.

Furthermore, it is found practically impossible to bring the apron to an exact bearing in the cockpit of the boat, there being a play of about $\frac{1}{2}''$ between the sill of the apron and its bearing on the boat, under favorable conditions. The sudden loading of the apron caused by the train coming on from the boat, immediately deflects the end of the apron to its bearing. To overcome the inertia of the counterweights and the pontoon, a transverse bending strain is produced in the end panels of the top chords.

A variation in the elevation of the sides of the boat during the operation of loading or unloading, produces a torsional action in the apron. Experience has shown that the action of the bending stresses and the stresses caused by the torsional motion of the apron are very destructive to a timber chord. It is believed that the addition of steel beams to the chord section will prove advantageous in resisting such stresses.

The variation in temperature has been assumed as 40° between extremes. With the work placed in position at a mean temperature,

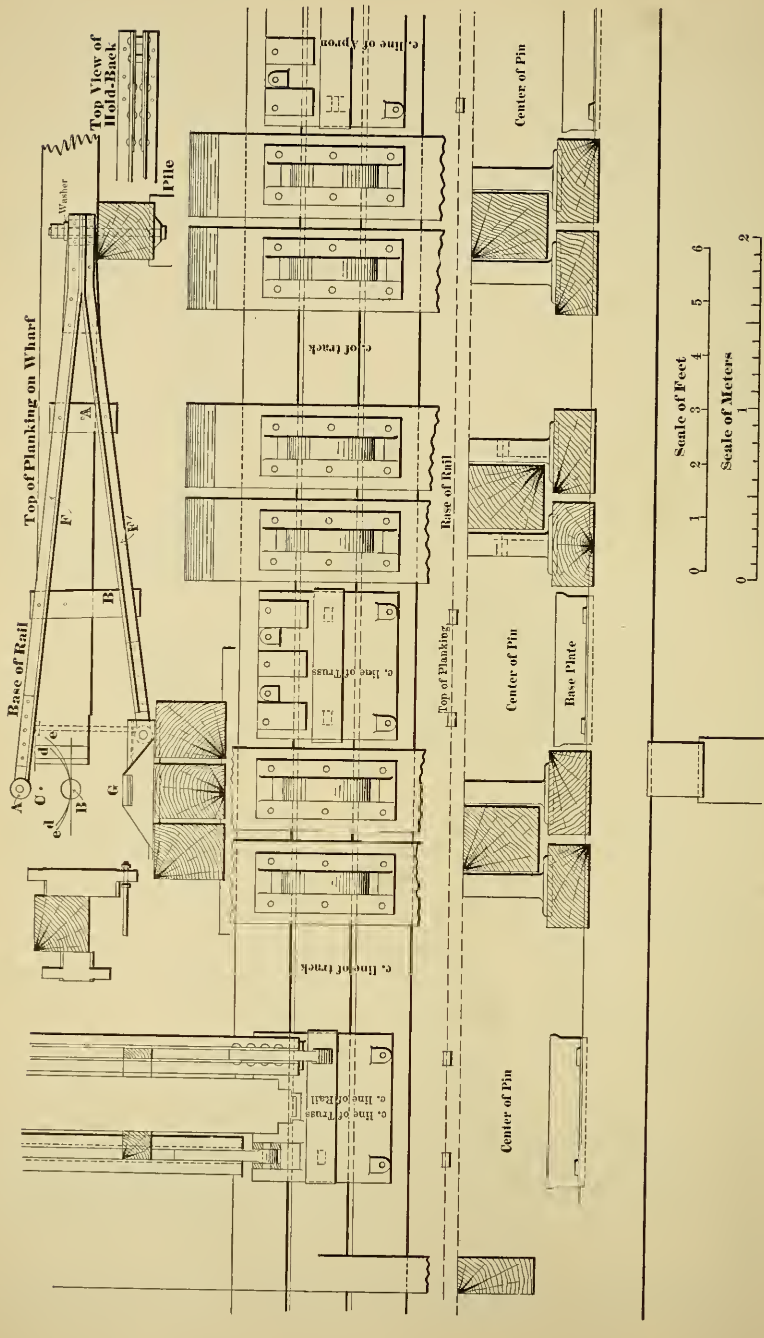

Top View of Hold-Back
Pile
Washer
Top of Planking on Wharf
Base of Rail
A
B
F
F'
G
C
d
e
c. line of Apron
Center of Pin
c. of track
Base of Rail
Top of Planking
c. line of Truss
Center of Pin
Base Plate
c. line of track
c. line of Rail
c. line of Truss
Center of Pin
Scale of Feet
0 1 2 3 4 5 6
Scale of Meters
0 1 2

FIG. 2.

the 40° variation will cause a difference in length of the timber and iron sections of about $\frac{1}{20}''$. The deflection of the pin will be sufficient to overcome this variation.

The stringers at the wharf end will fit into a casting which will have projections on its sides. The projections will be in the form of a segment of a curve, and will extend out from the face of the casting. This projection will rest in a socket of a similar concave curvature, in a pedestal casting which rests on the wharf. In this way an axis of rotation for the stringers is provided.

For the trusses the problem is very different. An inclination of the apron above or below the horizontal line passing through the hinge creates a thrust or pull at the hinge which must be resisted.

A large radius for the rolling face was necessary in order to secure sufficient bearing power. It was also sought to secure a detail which would cause the apron to automatically adjust itself to its normal position when horizontal. These conditions are believed to have been fulfilled in the detail adopted. The end pin *B* (Fig. 3) of the truss rests upon the rocker *R*, and transmits through it to the wharf the portion of the load that is brought to this end of the truss. The pin *A* (Fig. 2) is the hinge pin, about which the apron revolves.

The point *C* is the center of the curve of the bearing face of the rocker, the radius being 18″. The end pin *B* of the truss is 7″ below this center of curvature.

The hinge pin *A* is 11″ above the end pin *B*, and 22″ above the bearing point *G*. The pin *A* is held in a position that is at all times vertically over *G*, *G* being the center of pressure when the rocker is vertical. This is done by extending braces *F*, *F′* backwards from *A* and *G* and securing them to the wharf. The struts are joined to one another at the wharf end, and also at points intermediate between the wharf connection and the points *A* and *G*, thus completing the triangle of bracing. There are a pair of these braces to each truss. The apron is connected to the hinge by giving the pin *A* a bearing in the end casting. The horizontal motion of the pin *B*, due to the extreme position of the apron, was found to be about $\frac{1}{2}''$ each side of the vertical.

The path of motion of the pin *B* is along the curve *B*, *e*. If the hinge were held rigidly in position, its path of motion would have to be along *B*, *d*, consequently the hinge *A* will have to be deflected a distance equal to the space between the two curves *B*, *e*, and *B*, *d*. This distance was found to never exceed about $\frac{1}{32}''$, a deflection which will be given by the elasticity of the strut with ease.

The point *B* being below the center of curvature of the rolling face, the tendency of the apron must always be to return to its normal

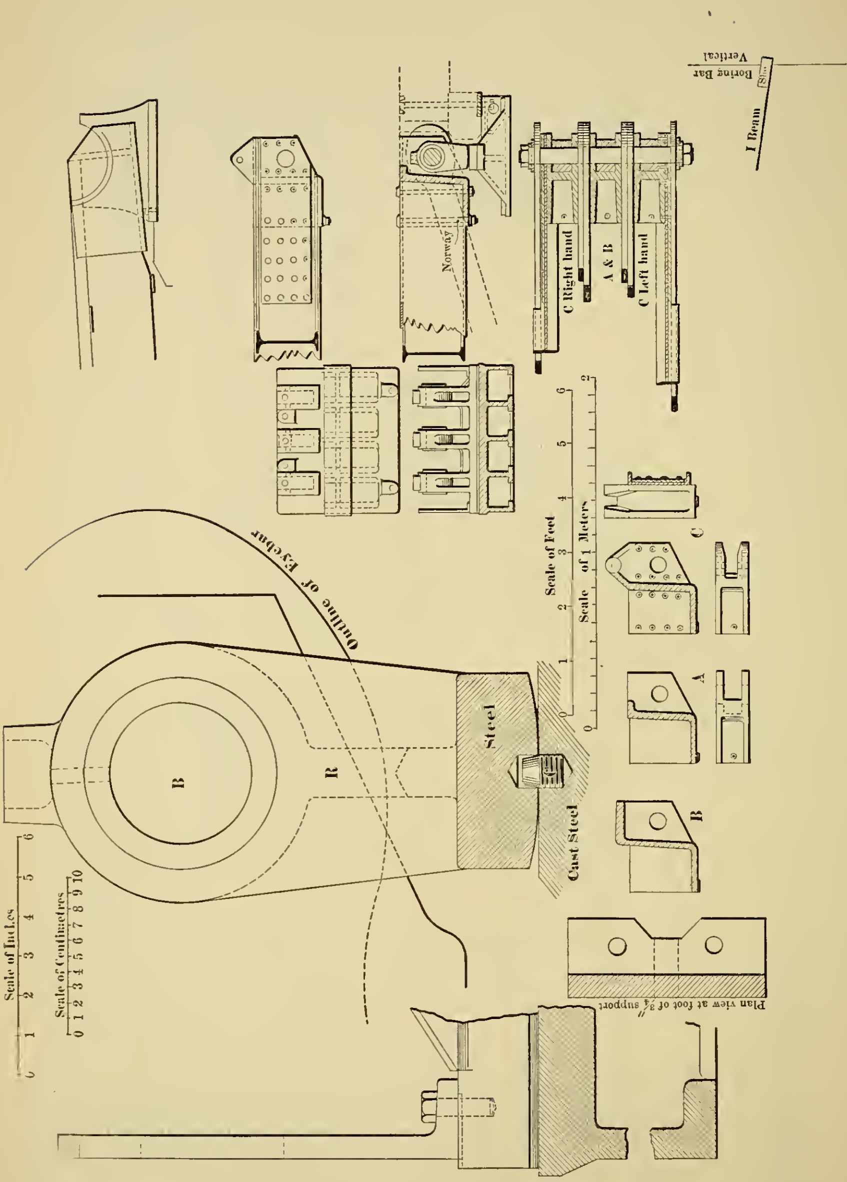

Outline of Eyebar
Steel
Cast Steel
B
R
A
C
Scale of Feet
Scale of 1 Meters
C Right hand
A & B
C Left hand
Norway
I Beam
Boring Bar
Vertical
Plan view at foot of 8/4 support
Scale of Inches
Scale of Centimetres

FIG. 3.

position. The stress produced in the strut F when the point B is at its maximum distance from the vertical line, is about 1,400 pounds. To prevent the rocker being lifted off its bearing through any blow or shock, the tap bolt C is placed in the pedestal.

The eyebars for this work were made by the Pacific Rolling Mill Co., of San Francisco. The balance of the shop work was done by the railroad shops at Sacramento.

PAMPHLET FILING.

By William H. Bryan, Member of the Engineers' Club of St. Louis.

[Read before the Club, October 16, 1895.*]

Every engineer comes into the possession of numerous folders, pamphlets, circulars and catalogues which seem worth preserving. If he is a member of one or more of the national societies, the number is increased. If, in addition, he is represented by cards in the professional directories, the amount of this literature becomes larger still.

These pamphlets are of every imaginable size and shape, and cover all branches of engineering, and are often on subjects of only indirect interest to the engineer. Unfortunately they differ widely in shape and size, from a single card or leaflet, to a bound catalogue of many hundred pages. The list comprises manufacturers' catalogues, stock and price lists, advertisements, specifications, reports, ordinances, results of tests, clippings, and miscellaneous pamphlets of a fragmentary character of every imaginable description. Much that the average engineer receives is, of course, not worth preserving, but, on the other hand, a considerable portion of it, if not of actual value at the moment, is well worth preserving with a view of its future possible use. Some of it is of great value, as it represents the latest practice in certain lines, which is not as yet old enough to be incorporated in the text-books, or engineer's pocket books, much of it not having even reached the engineering press. Many manufacturers add a value to their catalogues by incorporating in them numerous tables and formulæ. As a rule these are carefully collected and represent good practice. Not infrequently they contain data not accessible elsewhere. Some of these are so valuable that the engineer consults them frequently and keeps them close at hand. A good example of this is "Helios, a Text Book of Modern Boiler Practice," recently issued by the Heine Safety Boiler Company of this city. Others, however, are of quite a different character and some judgment must be used in determining their merits. Within the last week I received a circular in which the time-honored rule that the evaporation of a cubic foot of water per hour represented one boiler horse-power, was stated in all seriousness.

There can be no argument as to the desirability of preserving this matter, but unless a well-digested system of filing and indexing is employed, the accumulation soon reaches a point where it become unwieldy, and the difficulty—if not impossibility—of finding any desired pamphlet,

* Manuscript received November 11, 1895.—*Secretary, Ass'n of Eng. Socs.*

prevents any considerable use being made of them, and greatly reduces —if it does not wholly destroy—their value. Very early in my own experience I found that I must adopt a system which would make it possible to put my hands immediately upon all the accumulated matter upon any one of many different subjects. As other engineers have no doubt been confronted with the same difficulties, I have thought it might be of interest to explain the solution which I finally reached.

Any satisfactory plan must of necessity be simple in design and arrangement, complete, occupy little space, and not be expensive in first cost. It should be possible to remove and replace any single pamphlet without disturbing the others. Above all, the system must be so nearly "automatic" as to require the minimum of thought and labor to maintain it at its highest efficiency.

The large bound catalogues are, of course, easily handled. Most of

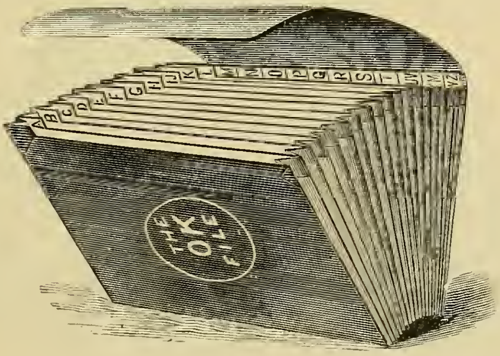


FIG. 1.

them are worthy of a place on the shelves of our book cases. The smaller and irregularly shaped pamphlets are the ones which present difficulties. In my early days a few heavy envelopes in three or four leading divisions of engineering answered the purpose. These were simply labeled as to their general character, and each individual pamphlet or clipping was also indexed. This was further increased by additional envelopes of the same character, as the accumulation grew. For obvious reasons, however, this plan soon failed, the envelopes being quite limited in capacity, and the system having little or no elasticity. The next step was the use of the flexible paper letter files, Fig. 1. These cost from 25 cents to 35 cents each, and contain twenty-two divisions. A label is placed on each division giving the title or subject to which it is devoted. These permit quite a variety of subjects and each division may be somewhat overcrowded. This system lasted me until within the last year, adding cases from time to time, and rearranging the subjects. I found in practice, however, that many of the divisions became badly

overcrowded, and that the cases would not stand the hard service due to frequent reference to their contents. Furthermore, the divisions are not readily accessible where the filing cases are all kept together on shelves, it being necessary to remove the entire case to get at any particular division. Dust also gets into the divisions.

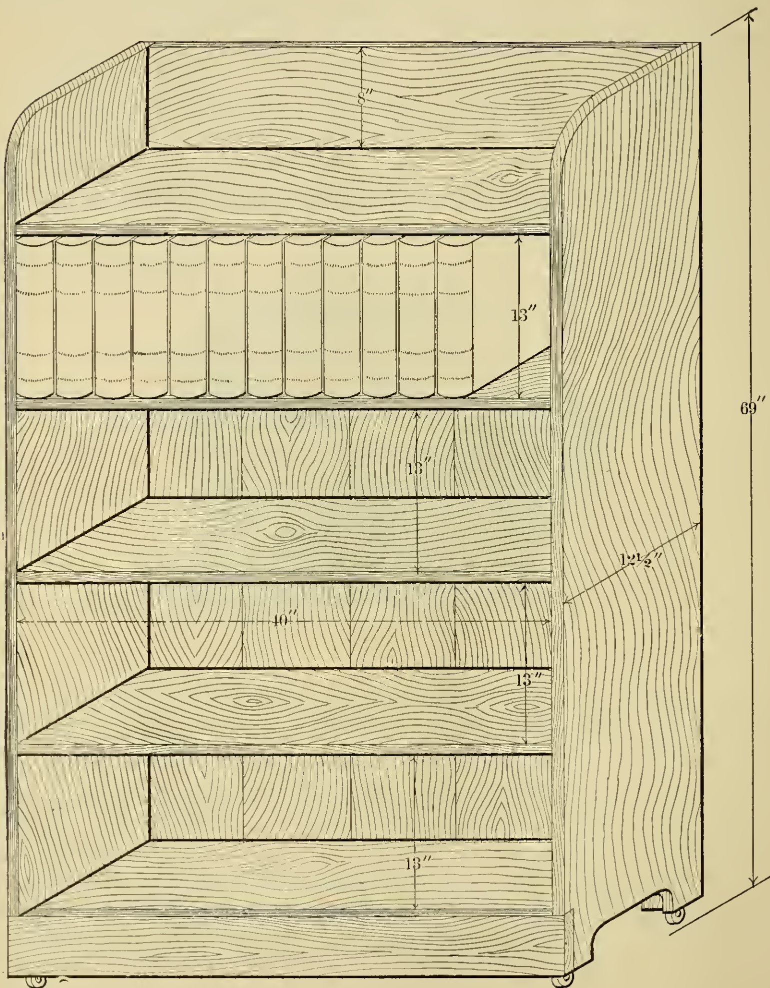


Fig. 2

Less than a year ago, I realized that it was necessary to radically change my system if I desired to be able to get the full benefit of the matter in my possession. I devoted a great deal of study to the matter, investigating all sorts of filing systems, shelves, cases of drawers, etc., but

found nothing which was at all suitable. The standard sizes were either not satisfactory as to size, or shape, or they occupied too much room, or were too expensive. The latter was true also of any special design which might be gotten up.

The accompanying sketch, Fig. 2, indicates my solution of the difficulty. I had a case of shelves made, of shape and dimensions shown. There are five shelves, each 40 inches wide and 13 inches high in the clear. The ends, tops, and facings of the shelves, are of antique oak; the rest of the case being of ordinary material, poplar, I believe. The case is on rollers.

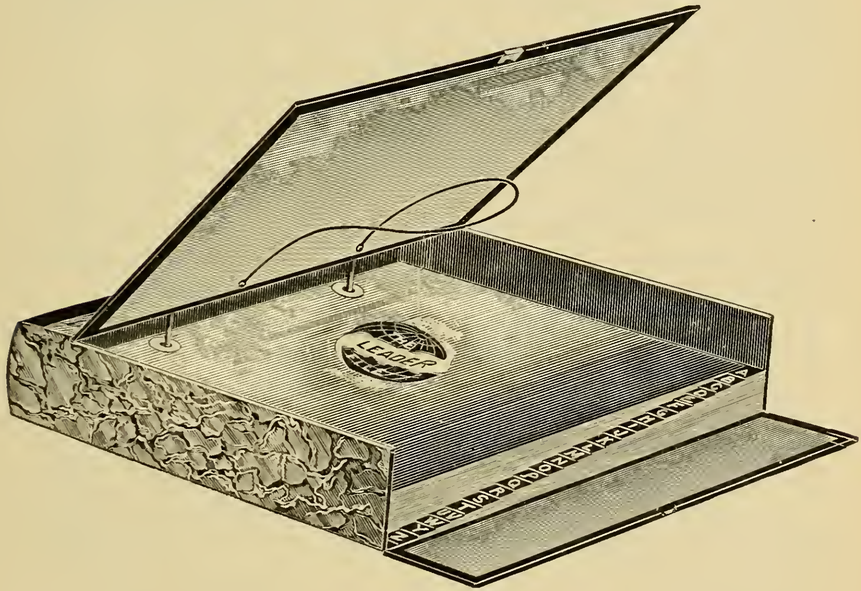


Fig. 3.

I then ordered five dozen "Perfection" letter file cases of standard size, which is 12 x 10½ x 2¾ deep, Fig. 3. I had partitions placed in forty of them, giving me eighty divisions of about 1⅜ inches depth, for ordinary use, the remaining twenty being full depth and intended for those subjects on which an unusual amount of matter had or might be accumulated. The cases are sufficiently large to receive any of the standard sizes of catalogues or pamphlets. In fact, there are but few odds and ends of eccentric shape that cannot be handled. The case of shelves cost $7.00 and the letter files $16.50, being $2.50 per dozen, with an extra charge of ten cents per case for the partitions; a total of $23.50.

Each of the five shelves contains twelve filing cases, with 3 or 4

inches of space to spare to permit easy handling, as well as some over-crowding of cases, or even an additional case on each shelf.

Each of the one hundred divisions is numbered, and bears also a label indicating its contents. In my desk I keep an index, which is a copy of the labels on the individual cases. When the literature is received, it is first examined to determine whether it appears worthy of preservation. If worth saving, it is placed temporarily in a convenient drawer in my desk. When this drawer becomes filled—which in my own case often happens two or three times a month—all the accumulated matter is gone over again and examined more carefully. On each pamphlet which I decide to preserve, I mark the number of the filing division into which it is to go. The whole is then turned over to an assistant, who files the pamphlets in their proper places.

When I desire to look up any particular subject, I turn to my index, ascertain the number of the division, and request an assistant to bring me the proper case. As my system of indexing is alphabetical, however, it is frequently quite as convenient to go directly to the shelves and pick out the case desired. If a single pamphlet is being consulted, it can, when I am through with it, be placed temporarily in the receiving drawer, if there is not time enough to file it away permanently.

In practice, I have found that still further division is necessary on some subjects. To carry these out I use large Manilla envelopes, each bearing a sub-heading corresponding to the branch of the subject it serves.

To carry out the system in its best shape it is necessary to go through the cases carefully every year or two, making provision for new subjects which have arisen, relieving over-loaded divisions; and weeding out duplicates and matter which has become antiquated, or is of doubtful value

The system represents an investment of but $23.50, but its value to me is many times that amount. If I include its contents, I can hardly place a value on it, as much of the matter could not be replaced. I can assure you that the ability to put my hands at once upon all the matter of this character which I have accumulated for years, on over one hundred subjects, is a profound satisfaction, and I feel that I have mastered the pamphlet-filing problem for some years to come at least.

A less elaborate system would answer for many engineers, and even the small investment required may not always be convenient to make. In such cases the filing by divisions in the ordinary flexible letter file, Fig. 1, will be found quite inexpensive and satisfactory.

STREAM MEASUREMENTS AND WATER POWER IN VIRGINIA AND WEST VIRGINIA.

By D. C. Humphreys, Member of the Association of Engineers of Virginia.

[Read before the Association, November 23, 1895.*]

Those of this Association who were present at the summer meeting in Lexington will remember that Mr. F. H. Newell, Hydrographer of the United States Geological Survey, was present, and gave us a talk on the work and methods of the Survey.

At that time, no work in stream measurement had been done in the Virginias, except along the Potomac River; since that time, at the request of the Survey, I have undertaken to do what I could in investigating the water resources of the States of Virginia and West Virginia as far as the limited amount of money that could be placed at my disposal for that purpose would permit.

I am satisfied that the work which has been begun will be of great value to the two States, if it can be continued and enlarged. Knowing the interest our Association takes in all such investigations, I offer this paper as a sort of progress report.

The origin of this investigation will be found in Major J. W. Powell's "Report on the Lands of the Arid Region of the United States," 1878, which was the result of surveys made under him. In March, 1888, the Director of the Geological Survey was directed to make examinations relating to water storage, the volume of streams, and similar questions.

October 2, 1888, the "Irrigation Survey" was created, and March 2, 1889, it was extended, but the appropriations for it were abruptly cut off in 1890, after which date stream measurements were carried on only incidentally along with the topographical surveys.

On March 18, 1894, an appropriation of $12,500 was made to investigate the water resources of the United States, and by Act of March 3, 1895, $20,000 were appropriated, which is the amount available to June 30, 1896.

In regard to the work Mr. Newell says: "In the attempt to carry on work in all parts of the United States, as well as to pay all incidental office expenses, it results that the amount for any one locality is very small, especially in the East; since the arid regions demand the larger share of attention."

* Manuscript received December 5, 1895.—*Secretary, Ass'n of Eng. Socs.*

The reasons for the larger share going to the arid lands is not hard to find.

I. The General Government owns about one-third of our territory by absolute right, and the investigation is calculated to greatly enhance the value of the Government's own property.

II. The value of water, on account of the very limited supply, is much greater in the West than in the East; and, to use the rivers to the best advantage, in the arid region, it is necessary that a comprehensive plan should be adopted, which the separate States cannot do, as the rivers go from one State to another, and so pass from one control and jurisdiction to another.

III. The question of artesian wells and storage can only be answered after a comprehensive and extended survey, and geological investigation, such as the U. S. Geological Survey is now making.

IV. On account of the vital importance to them, Western representatives in Congress have been zealous in getting appropriations passed for the purpose, with the tacit understanding that the money should largely be spent in their section; in which there would seem to be some justice since they have no harbors nor navigable rivers to improve.

The complete success of the gigantic scheme for utilizing some of the power of Niagara, together with many even greater successes, on a smaller scale, in transmitting water power electrically, has turned the attention of our profession, and fired the imagination of the general public, to the splendid possibilities of using the vast wealth of power which is now going to waste in our water courses in the Appalachian Mountains.

The best water powers have a way of being in places very difficult of access, but the perfecting of the alternating motor under Nicola Tesla and others has made all water power available, as it can be easily transmitted to towns and railway stations. The cost of electrical apparatus is such that it cannot be said the transmission can be cheaply done, especially when the current has to be transformed up, then down again, which is necessary if the distance be long; so that in many cases the railway coal car will remain the cheapest transmitter of energy.

The newly acquired importance of all water powers has attracted the attention of our public men, and as a result the investigation of the water resources of the United States now includes the East as well as the West, and especially the mountainous portions of the East.

To properly carry on the investigation the Survey should have enough money, so that at least $20,000 could be annually spent on the Appalachian region alone. It is to be hoped, Congress will see its way clear to provide for this work, and the justice might be put on the same ground as it is in the far West, that we have neither harbors nor navigable waters in the mountain country.

The value of this investigation of water power need hardly be pointed out to this Association; still it will be proper to state not only what has been done, but also what is proposed, and what sort of information we hope to be able to give those contemplating the use of water power.

In the Virginias, stations have been established and measurements are being made: *On the Potomac* at Dam No. 6, near Great Cacapon, W.Va.; on the South Branch, at Springfield, W. Va.; on the main river at Cumberland, Md.; on the Shenandoah near Millville, W. Va.; on the Potomac at the Point of Rocks, Md., and at Chain Bridge, D. C. At these stations the work has been largely done by Mr. C. C. Babb, Assistant Hydrographer of the Survey,* who also assisted me in selecting and establishing most of the following stations which I am now looking after. *On New River*, at Lafayette, W. Va.; on the *Greenbrier*, at Alderson, W. Va.; on the *James*, at Buchanan, Va.; on *North River*, of the James, at Glasgow, Va.; on *North and South Rivers*, of the Shenandoah, at Port Republic, Va.; six stations in all.

The observations at each station consist of two parts.

(1) The river height is daily read by a gauge reader, who lives close to the station, and a weekly report is made to me, which, after copying it, I send on to Washington.

(2) The relation must be established between river height and discharge per second; when this is once done all that is necessary in order to ascertain the quantity of water flowing by per second is to measure the river height, or read the gauge, then by a rating table or diagram determine the discharge.

To obtain trustworthy results it is necessary that the station be chosen at a place where the cross-section and channel above and below shall be permanent. This can be easily done in the mountains or rocky country, while on the Mississippi and Missouri Rivers, where I was formerly engaged, it was an impossibility.

To establish this relation between gauge reading and discharge, measurements must be made at different stages, from extreme high water to extreme low water; thus establishing points along the curve expressing such relation. It is obvious that for power purposes the low water discharge is the important one, and therefore more measurements are made at low water than at any other stage. High water discharge is important as effecting the elevation to be given the buildings above the crest of a newly erected dam, also as effecting storage.

* The results of some of his work were given to the public in a paper, "The Hydrography of the Potomac Basin," by Cyrus C. Babb, *Transactions of the American Society of Civil Engineers*, XXVII, pp. 21–38, July, 1892.

In this work I am using one of two meters which are at my disposal.

(1) A Haskell electric meter, which is let down usually from a bridge attached to a compound electric cable which serves as a cord to hold up the meter, as an electric conductor for recording the revolutions of the wheel, and as a sounding line, being tagged with red and white for that purpose. A heavy weight attached to the bottom of the meter causes it to sink nearly vertically in the water while the tail keeps the wheel pointed towards the current. The electricity is furnished by a small (2″ x 1″) bisulphate of mercury wet battery, which is a model of compactness and convenience, and it always works whenever I have tried to use it, which I consider a big compliment to any field electric battery. I can't say so much for the electric part of the meter, for I nearly always have some trouble with it, owing usually to a little water getting into a place where it is not wanted. When, for any reason it don't work well, it is a matter of the utmost importance not to be in any hurry while fixing it.

(2) A meter made by Newton, of London, such as is supplied to the Admiralty, this one belonging to Washington and Lee University. The registering apparatus is put in gear by pulling a string, and released by slacking the pull; this makes it almost necessary to attach it to a rod, so that it cannot be used in measuring from a bridge. It is specially adapted to measuring by wading, and is well suited to work from a boat. It has the merit of being simple and cheap, so that it can hardly be recommended it too highly.

Wherever it can be done, a bridge is selected, because of the cheapness of gauging from it, and discharge measurement can be made by one man, if necessary, while no more assistance is needed than can be rendered by a boy. Next in order of desirability is a cable, on which a small car travels, large enough to hold one man, who lets down his electric meter from the car, while he gets his distances from the bank by a tagged wire suspended above the cable. This method has the disadvantage of being costly to construct, but has the advantage that you can locate it at a suitable place for accurate measurement.

In warm weather, and low water in the smaller streams, wading is the best method.

The method to be used when all others fail, is to work from a boat, which, if the stream be narrow, is pulled along a cable, while, if it be wide, the position of the boat will have to be located by some indirect method.

The following stream measurements have been made in the Virginias, not including the Potomac measurements:

River.	Locality.	Date.	Discharge, in cu. ft. per second.	Water Power per foot Fall.
New,	Fayette, W. Va.,	July 29, '95.	7128	810.0
"	" "	Sept. 4, "	3030	345.0
Greenbrier,	Alderson, "	July 30, "	457	52.0
"	" "	Sept. 4, "	106	12.0
James,	Buchanan, Va.,	July 3, "	509	57.9
"	" "	Aug. 1, "	543	61.8
"	" "	Sept. 6, "	397	45.1
North (of James),	Glasgow, "	Aug. 24, "	201	22.8
" "	Lexington, "	Aug. 2, "	135	15.2
" "	" "	Sept. 7, "	82	9.3
" '	" "	" 17, "	81	9.2
North (of Shenandoah),	Port Republic, Va.,	Aug. 6, "	374	42.5
" "	" " "	" 29, "	258	29 3
South, "	" " "	" 6, "	114	13.0
" "	" " "	" 29, "	87	9.9
" "	Basic City, "	" 5, "	72	8.2
North Fork, "	Riverton, "	" 7, "	362	41.0
South Fork, "	" "	" 7, "	791	90.0

The measurements made in the latter part of August and early in September, give the low water discharge, nearly, except in the case of New River, which was on October 4th, two feet lower than when it was measured September 4th.

The largest power that I have seen, and probably the finest in the two States, is in the New River Cañon, where the fall is over twenty feet to the mile, and the distance is about sixty-four miles. Taking my smallest measurement, that of September 4, 1895, the total horse-power going to waste in the cañon is 442,300, sufficient to move about 1,000 trains, to do which with coal would require over 1,000 tons of coal per hour.

This vast power is situated in the midst of one of the finest coal fields in the world, where power from steam is cheapest, so that its use may be postponed, but it will some day be developed, when our inexhaustible coal fields are in the same condition that our inexhaustible forests now are. But it may come sooner, when the C. & O. R. R. shall use it for driving its trains by electricity, and passengers on the F. F. V. can see Hawk's Nest without getting cinders in their eyes. Should this road use the New, the Greenbrier, and the James in this way, supplemented by central steam power stations, if necessary, there would be no question as to how most people from west of the Appalachians would reach the capital of their country.

In this connection I take pleasure in saying that the C. & O. R. R. has shown great interest in the work, and has given very material assistance. If future appropriations permit, the work will be ex-

tended to cover the entire State; and since the results will benefit no interest so much as the railways, it is hoped and believed that the other railways will help in collecting trustworthy information about the water powers in the sections through which they run.

As to the use to be made of the work that is now being done, I can best explain by supposing a manufacturer to be looking for cheap power. He finds a site, has the available fall measured at that point, and wants to know the quantity of water. If he is on a stream that we have measured and recorded—that is if he is at or near one of our stations—we can furnish him the water power for each day in the year for several years.

Should he not be on one of the measured streams, but on a tributary, he has one measurement made, then the Geological Survey will tell him what the variations through the year will probably be; assuming that streams flowing from similar catchment basins will vary with the rainfall in each. If the rainfall is about the same in each basin, the assumption may fairly be made that the tributary will vary as the main stream does. Similar catchment basins means that the geological formations shall be the same or nearly so.

It is proposed to extend this branch of the work of the Geological Survey by making at least one measurement of each river or creek that may be useful for water power at as nearly low water mark as possible. This will give the critical point in regard to each stream, and the low water ratios being established, the other stages may be estimated with sufficient accuracy for practical purposes.

In conclusion I will say that the Geological Survey will be glad to get the record of any fairly accurate stream measurements that have been made, or any other trustworthy information in regard to the water power of the Virginias.

PROGRESS OF THE AMERICAN PORTLAND CEMENT INDUSTRY.

BY ROBERT W. LESLEY, ASSOCIATE AM. SOC. C. E.

[Read before the Boston Society of Civil Engineers, November 20, 1895.*]

IN order to properly give some idea of the Portland Cement Industry in the United States, it seems to be wise, though, to so intelligent a body as I see before me, almost unnecessary, to go into, in a brief way, the distinction between natural and Portland cements, and to give generally an idea of exactly what is meant by those terms when used in connection with cements. So also, while the history of the manufacture of cement in the world dates back to the Roman days, and is no doubt familiar to you all, yet in considering the latest and newest developments in this industry in possibly the largest cement consuming country in the world, a few words upon the history of cement, both natural and Portland, may not be uninteresting.

To begin with, therefore, I would say generally that cements are divided into natural and Portland cements. A natural cement is, as its title implies, a cement formed by nature; that is to say, certain argillaceous limestones, containing varying percentages of lime, silica and alumina, are quarried and without further manipulation are, in their natural condition, calcined in open lime-kilns at low temperatures. The resultant product when ground to powder is the natural cement found on the market. In order to illustrate just what is meant by natural cement, a natural cement rock of the Lehigh County, Pennsylvania, district may be taken as a sample. The rock in question, which is of a laminated character, shows to the naked eye, and much more so under the microscope, various laminæ or leaves of varying material; for practical purposes, it may so happen that one of these small layers is lime, another alumina and another silica, or there may be a large layer of lime, two layers of silica together and a small layer of alumina. As can be readily understood, this rock, when calcined under either high or low temperatures, will not under the heat of the kiln, combine in all its elements or parts; consequently for purposes of comparison between natural and Portland cement, it may be broadly stated that from 20 to 25 per cent. of the natural cement is inert or not in combination. This can also be determined by synthesis as well as analysis of material. By taking the portions of silica and alumina that should combine properly

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* Manuscript received December 7, 1895.—*Secretary, Ass'n of Eng. Socs.*

with the lime, it will be found that there are certain proportions in excess, and therefore uncombined. These natural rocks are burned at light heat with coal, and when drawn from the kilns are not very hard and are with comparative ease crushed and ground to powder. In this class of cements may be reckoned the well-known cements of the Rosendale, the Potomac, the Lehigh, the Akron, the Louisville, and the Utica districts; all of them excellent in their way, and all of them having been used with success in large work all over the United States.

Portland cement, on the other hand, is essentially an artificial product. While in nature there are found in the Lehigh District, at Boulogne, in France, in Belgium, and in small quantities possibly at one or two other points in the Southwest, natural rocks, which, when calcined at high heat, vitrify and form clinker similar to the ordinary Portland cement clinker, yet experience has shown that owing to the changing of the rocks, the shifting of the strata and the uneven distribution of the chemical elements of the lime, silica and alumina in the mass, they are not to be relied upon to make cement in a large way of uniform grade and reliable character. Therefore, going back to the use of the word "artificial," it was found that to make cement of the uniform character required of Portland cement, that broadly speaking, it was absolutely necessary to make artificially in some way, a new material before the calcining operation. In England, the home of Portland cement, this was done by the original discoverer of this new material by mixing together in a wet way, chalk and the blue clay or mud from the English rivers. In France the same result is achieved by adding to the Boulogne material, sufficient amounts of clay or chalk to bring it to a uniform character, so far as chemical analysis is concerned. In Germany, marls are added to clays, limestones to clays, and in Belgium, lime or clay to natural cement rocks, and also chalk to clay. In all these cases, the broad process has been to mix the two ingredients carrying respectively, first lime, and second, the silica and alumina in a raw condition, with water; the material having prior to that state of the process been reduced to the condition of a fine pulp or powder, according to whether the grinding was in a wet or dry way. The material thus produced, whether by wet grinding in the shape of a cream or paste, or by dry grinding in the shape of a mud, is either allowed to dry, or is dried artificially and is made into bricks, blocks, balls or other forms. This new *artificial stone* as I shall call it, is as you can all see by the foregoing description, composed of finely comminuted particles of lime, silica and alumina, all in close mechanical union, and when of soluble material in many cases in chemical combination. The rock which I take as an illustration is from the Lehigh District. It shows these laminæ of the various ingredients in their natural condition, not in close mechanical or chemical union. The powder pro-

duced by grinding the raw rock shows the same rock, which is practically, by chemical analysis, suitable for manufacture of Portland cement, broken down and distributed into atoms or molecules. The powder is mixed with water and made into the form of bricks. The bricks are made up of small grains of powder which, re-arranged mechanically with the lime, silica and alumina that were formerly in separate laminæ, or not thoroughly mechanically combined, now brought in thorough mechanical combination, and ready in this new form of a *new artificially made rock*, to be acted upon in a chemical crucible. For further illustration may be considered the marl and clay from New York State, which for practical purposes may be stated to represent the chalk and clay of England or the marl and clay of Germany. An examination of the materials will show their marked differences, while an examination of the brick made therefrom will show again a *new rock*, with the elements in close union and ready for the kiln. The kiln therefore, in the process of cement manufacturing, may simply be considered as a large chemical crucible, where the bricks or blocks of the raw material are placed between layers of coke and where under the fierce heat of the kiln the material is brought into a state of incipient vitrification, and the chemical union is formed between the silica and alumina and the lime, forming what may be called double silicates or alumina and lime, though generally speaking, the chemistry of exactly what does happen in the kiln is still an uncertain subject, and many interesting papers and examinations by such chemists as Fremy, Le Chattillier, Feichtinger and Landrin show many varying points of view on this subject. After this calcination, the material which is drawn from the kiln, is in the shape of blackish green masses of clinkers, and while the cement-making material may vary in many parts of the manufacture, the calcined material or clinker is as a generality all about the same color, though slightly varying in weight according to the lightness or heaviness of the materials composing the brick, and the degree of the density of the brick before they are put in the kiln. This may be exemplified by comparing samples of the clinker which is made from the marl and clay material, and that made from cement rocks and limestones.

The grinding of Portland cement is a much more difficult matter than the grinding of natural cement. It requires larger grinding machinery as well as greater grinding power. This is due to the difference in the texture of the Portland cement clinker and of the stone of the natural cement after calcination.

While what I have stated may seem somewhat unnecessary to so well posted an audience, it nevertheless will convey, by means of an object-lesson with the materials before you, just exactly what is meant by the two definitions of cement that we are all using, and in many cases

possibly without much thought as to exactly what is meant by them. So much, therefore, for the definitions of cement.

As to the history of cement, we all know that long before any of us were born or even thought of, the Romans had some sort of a mortar made from combinations of lime and volcanic dust, which was left for one or two years in the shape of a paste made with water, and after it had thus thoroughly seasoned in pits or vats was used in the work that the ancients did in the way of masonry. Little new information on the subject of mortars was developed in the world from that time until the reign of Louis XIV, of France, when a new method of making mortar by the use of lime hot from the kilns was brought before him, in the shape of a petition or address for recognition of this new discovery.

In 1756, Smeaton, who in 1791 described his experiments when writing of his construction of the Eddystone lighthouse, first developed the thought which led to the discovery of the ingredients of hydraulic mortar, and he laid down the principle that the hydraulicity of a limestone depends not, as was formerly thought, upon its color or its texture, but upon the percentage of clay entering into its chemical composition. This discovery naturally caused a general examination by engineers and others of various limestones and other materials in England. Almost contemporaneous with Smeaton's publication came the patent of Jos. Parker, who claimed to make Parker's cement out of certain stones or argillaceous productions. This patent he followed up in 1796 by a second patent for the use of the nodules or "noddles" of clay which he found along the Kentish coast of England. To this cement, later on, the name of Roman cement was given, and it commanded quite a large market in England. Almost contemporaneous with the work of Parker, but still following Smeaton's great discovery, Lesage, who was connected with the French army, found similar pebbles or noddles at Boulogne, out of which he made good quick-setting cement along in 1796. Chemically speaking, all these cements so far mentioned were natural cements, and analyzed very near alike, containing about 45 of lime to 30 of silica and alumina. In France also, Vicat, whose work on mortars for construction, limes for construction, betons and ordinary mortars was published in 1818, had followed up Smeaton's discovery, of the advantage of clay in natural limestone to make such limestone hydraulic—by producing artificial hydraulic limes, by mixing with rich lime varying percentages of clay, doing what he describes in his book when he says, "We have no longer therefore to attend to laboratory experiments, but indeed to a new art, very nearly arrived at perfection." This new art, which he describes in 1818, was what is now the art of making Portland cement, though he did not describe it by that name, nor did he in his early experiments arrive at the final results which he

subsequently attained. At or about the same time that Vicat was experimenting, Jos. Aspdin, a bricklayer of Leeds, England, was carrying on, in a less scientific way, a similar line of work which resulted in 1824 in his taking out a patent for an improvement in the mode of producing an artificial stone, which patent is generally recognized as the first description of the process of making Portland cement, though in point of fact neither the Aspdin patent, nor that of Frost, nor St. Leger, which were taken out in England at or about the same time, would actually make the Portland cement of the present day, because a careful examination of these patents shows that they fail to state that it is necessary to carry the calcination to incipient vitrifaction, though possibly this fact may or not have been withheld as a trade secret, for in the early days of the cement manufacture in England, the business was invested with the greatest amount of secrecy. As a bit of cement history it may be here stated, that in the face of the greater cost of producing Portland cement, the reputation of the English natural cements was so great that for several years after the establishment of Portland cement works the natural product commanded a higher price than the artificial one. It may be interesting, also, to know, in connection with all this business of Portland cement making, that as a general fact, in nearly every case, the large cement works of the world all owe their origin to patents of some kind. The great English works of J. B. White & Co. on the Thames, of Francis & Co. on the Thames, may be traced to the Frost patent of 1822; the cement works at Wakefield, England, which were established in 1825, and which still are in existence, grew out of Aspdin's patents, while other works on the Thames and at New Castle grew out of discoveries of a son of Jos. Aspdin and of a foreman of one of the original works started at the time of the Frost patent. This is especially the case with the Portland cement works of the United States. The spread of the cement industry into Belgium through a son-in-law of Aspdin, and thence into Germany, is not of much historical interest, except so far as it may be stated that Germany to-day is the largest producer of Portland cement in the world, and possibly the most scientific manufacturer. The French exploitation of cement manufacture came out of the inventions of Vicat, followed by the discoveries at Boulogne-sur-mer, at Vassey and at Tiel.

Having thus defined the character of the cements of commerce and briefly given a history of how, within the last hundred years, these two great elements in the building industry were discovered and brought before the public, I think the time has come to say something of what I think is the most interesting subject, and that is the development of the manufacture of cement in the United States. This history, in its incipient stages, almost synchronizes with the history of the development

of the great artificial water-ways or canals of the United States. When the Erie Canal was built, hydraulic mortar was a prime necessity, and out of that necessity grew the discovery of cement-making material near Fayetteville, N. Y., in 1818, and near Lockport, N. Y., in 1824. Natural cement is still made in these two districts, which are known as the Onondago Co., N. Y., and the Akron, N. Y., districts, though the distinct Akron District was not actually opened until some years later. The construction of the Delaware & Hudson Canal, from Rondout on the Hudson to Honesdale, Pa., brought about the discovery of the Rosendale District, where nearly 3,000,000 barrels of natural cement are annually produced, and which district was first opened in 1826. The Louisville District owes its discovery to the Government Canal which was commenced in 1829, for the purpose of facilitating navigation around the Falls of the Ohio at that point. Nearly 2,000,000 barrels annually are the output of that district, which ranks second only to the Rosendale field. When, in 1836, a canal was to be built to connect the coal and mountain district of Maryland with tide-water at Georgetown, necessity, that universal mother of invention, again led to the discovery of cement at Cumberland and at Round Top, the present centers of what is known as the Potomac Cement District. The well-known cement of the West, produced in the Utica, Ill., District, was discovered in 1838, for the purpose of supplying cement for the Illinois and Michigan Canal, which was then building locks and bridges in that vicinity. To the building of canals, again, are due the construction of cement works at Balcony Falls, Va., which cement went into the construction of the Richmond & Allegheny Canal, and the works at Siegfried, Pa., the pioneer mills in the Lehigh Valley District, are due to the construction of the Lehigh Canal.

In addition to these natural cement works, due to the construction of canals, may be mentioned the large mills at Milwaukee, on the lake and rail, and the works at Cement, Ga. All these cement works produced in the year 1894, nearly 8,000,000 barrels of natural cement, and, as showing the effect of competition in this industry, it may be stated that in 1884 a product of just about one-half the number of barrels yielded as many dollars as the entire product of 1894.

The quarries of all these natural cements vary largely in their character, some being mines and other open-face quarries. The rock in some cases is crystalline and in others laminated, and the chemical constituents vary largely between argillaceous limestones and argillaceous dolomites; in either case the process of manufacture is about the same and is similar to that described above. There are differences, of course, in the character of materials and analysis, but they are almost insignificant, and the process in the manufacture of natural cement

shows very little change from the date of its earliest establishment in this country, though the quality has improved largely and the cements have obtained a great and well-deserved reputation for uniformity and durability.

The reputation of Portland cement in Europe, established by its use in the London Sewage Department under John Grant, and by its extensive use on docks and other public work all over Europe, soon reached America, through engineering publications and through the practical knowledge engineers had of it, who came from Europe to this country to engage in large engineering work here. As far back as 1865 it was an article of importation, and was used sparingly for side-walks and the more difficult character of engineering works. The imports were small, and the article being one not generally known, prices were large and the business limited. Attention, however, was called to the material by the steady growth of the imports and by the general acceptability of this new article of trade. Work was done with it which could not be done with natural cement, and most excellent results were obtained. American ingenuity, always ready to seek new outlets for its labor and for its capital, soon began studying the manufacture of Portland cement. At Wampum, Pa., on the Allegheny River, near Pittsburg, Pa., cement works were established for the manufacture of Portland cement from limestone, in the early seventies. The location was admirably adapted for the business; the material being on the ground and a seam of coal being in close proximity. Under the management of a Mr. Shinn, Portland cement of excellent quality was produced, and was exhibited at the Centennial World's Fair, in Philadelphia, in 1876. These works are still in existence, are owned by the National Cement Co. of Pittsburg, and while they have not been largely increased, are still doing business. At about the same time, Mr. D. O. Saylor, in association with Mr. Esias Rehrig and Adam Woolever, of Allentown, Pa., came to the conclusion that a Portland cement could be made from the natural cement rocks of the Lehigh Valley, which they at that time were manufacturing into what was known commercially as "Anchor" natural cement. Mr. Saylor's first idea was that he could take these natural rocks and burn them at high temperatures to incipient vitrifaction, and by grinding that product make Portland cement. The first results justified his expectations—the rock did clinker; did resemble Portland cement clinker, and when ground and made into briquettes gave results on the testing machine equal to the best imported brands. He manufactured a large quantity of it, but suddenly found he was doomed to disappointment, for the material, owing to the irregularities in the laminæ of the rock, was not homogeneous, and at long periods the briquettes, pats, and work made with the cement, all began to fall away

and disintegrate. At that time he had a large stock of this cement in bins, and was driven to his wits' ends to know what to do with it. He put his brains to work; had analyses made of his rock; found that the analysis was near the Portland cement of commerce, and without anything but his native wit to guide him, ground the raw material into powder, made the powder into brick, sent to England for designs of the kilns then in use on the Medway and Thames, and actually made Portland cement, and, strange to say, when later he came to look at the bins of damaged cement he had on his hands, he took lumps of that material which had hardened in the bins, and, by re-calcining to clinker, made excellent Portland cement. Cement of this manufacture was also exhibited at the Centennial Exposition of 1876, where both Portland cements, the Wampum and the Saylor, held their own with the foreign brands then exhibited. Mr. Saylor was assisted in his work by Mr. John W. Eckert, a graduate of Lehigh University, who was for many years his manager, and who subsequently became President of the American Cement Co., at Egypt, Pa., in close proximity to Saylor's works. The works erected by Mr. Saylor are still in existence under the name of the Coplay Cement Co., and make excellent Portland cement, which is sold as "Saylor's Portland Cement."

In the Rosendale District on the Hudson, a number of gentlemen undertook to make Portland cement out of Fuller's earth and lime, under patents of C. F. Dunderdale. Works were erected, but it was found that the cost was so far out of proportion to the price that could be realized, that these works, which were established in 1876–77, were finally abandoned, as were other similar works subsequently established under the name of the Walkill Portland Cement Co., in the same district.

The Buffalo Portland cement, of which small quantities were manufactured for a few years along from 1878 to 1885, was due to the discoveries and patents of Uriah Cummings and L. J. Bennett, who were connected with these works, and who found by selecting the overburned material from the common cement kilns of the Buffalo Cement Co., a material resembling Portland cement could be made. The rock, however, was largely magnesian, and for this reason no great quantities of Portland cement were made.

The next large development in the manufacture of Portland cement in this country grew out of patents issued to E. J. DeSmedt, J. M. Willcox and R. W. Lesley, during the years 1883, 1884, 1885, and the co-operation with these gentlemen, of Mr. John W. Eckert, who, as already stated, had been one of the pioneers in the manufacture of Saylor's Portland cement at Coplay. The American Cement Company was the outgrowth of this combination, and is to-day the largest manufacturer

of Portland and Improved cement in the United States, and one of the largest manufacturers of natural hydraulic cement. Its original mill, the Egypt Portland Cement Works, was started in 1884, at Egypt, Lehigh County, Pa., and is still a large producer of Portland and other cements. Near by, it has been supplemented by two other large works, under the same management, the Pennsylvania Portland Cement Works, and the Columbia Portland Cement Works, while a fourth works, owned by the same company, is at Jordan, Onandago County, New York, just beyond Syracuse. The first three of these works manufacture Portland cement from natural rocks and lime, while the Jordan works produces its Portland cement by an admixture of marl and clay. The machinery in all these mills is of the most approved character, both for burning and grinding, and four Corliss engines of 600 horse-power each, one Naylor engine of 300 horse-power, and another Corliss engine of 125 horse-power, supply the motive power to drive the machinery.

The cement produced at these mills is known as "Giant Portland Cement" and has been used largely on public work all over the United States.

About the same time that these works were being established Portland cement was manufactured in a small way at Rockland, Me., by the Cobb Lime Co., but owing to the cost of fuel the manufacture was discontinued. As an outgrowth of patents of J. Murphy and N. Lord, Portland cement works, which are still running, were established at Columbus, Ohio, about 1885, for the manufacture of Portland cement from slag, lime and clay. In Texas; at about the same time, the Alamo Portland Cement Works were established at San Antonio, and produced cement from an admixture of a natural cement rock and a species of chalk there found. Chicago also entered into the business, and attempted to make a commercial Portland cement by importing Portland cement clinker from Europe and grinding it up with raw limestone to produce a commercial artificial Portland cement; while Louisville, not to be outdone, inasmuch as all the other natural cement districts were experimenting with Portland cement, undertook, under patents of Anderson & Brice, to make Portland cement by calcining, at high temperatures, small pieces of magnesian rocks and also by combining limestone and marl and shales for the same purpose. Colorado also was not behind-hand, and works were established there for the purpose of making cement at Colorado Springs, and also at Denver, out of the sulphate of lime rocks found near Manitou. One of these works was in existence until last year, when it was burned down. Two Englishmen undertook to manufacture cement under the English process, and established themselves in the early eighties at South Bend, Ind., where they were quite successful in manufacturing cement out of

marl and clay, and founded a works which is still in existence. Subsequently, these gentlemen, the Messrs. Millen, were the pioneers in opening up the marl and clay deposits around Syracuse, where they established works which are now the Empire Portland Cement Works, which they subsequently sold to build new works for themselves further west, at Wayland, N. Y. All these works manufacture cement practically under the same general process, though of different materials, ranging all the way from natural argillaceous limestones down to mixtures of clay and marl. All of them use the same general form of kiln such as are used on the Thames and Medway in England, and on the Rhine in Germany, and all of them vary slightly in the character of their grinding machinery. Other Portland cement works, manufacturing cement under these same methods, are located at Siegfried and Whitehall, Pa., at Bellefonte, O., at San Diego, Cal., and at Yankton, South Dakota.

At about the same time the American Cement Company were getting under way at Egypt, new experimental works were started on the Hudson by Jos. F. De Navarro and others operating under patents granted to Henry Mattey about the years 1885-86. These patents were for roasting small pieces of natural cement rocks in rotary kilns, and calcining them to incipient vitrifaction at the great heat produced by petroleum vapors injected into the rotating cylinders. The works on the Hudson, by reason of the non-adaptability of the materials, proved a failure. The particular form of kilns also were unsuccessful, but subsequently by adopting kilns and processes under inventions of Ransome, of England, the process of making cement in rotary kilns began after its removal from the banks of the Hudson to Coplay to take on a moderately successful aspect. The calcination of gypsum in revolving cylinders had been done under the Smith process in Philadelphia with excellent success, and Ransom's process was the application of this theory to another material. Works were established in 1886, on the Lehigh River, Pa., and are to-day manufacturing a large quantity of Portland cement under the name of Atlas Portland. Other works operating under different methods, but still making Portland cement under the rotary process, are in existence at Whitaker, N. J., and at Vulcanite, N. J., under the names, respectively, of the Alpha Portland Cement Co., and the Vulcanite Portland Cement Co. The cements made under this process generally carry admixtures of 2 to 3 per cent. of calcined plaster to counteract the quick-setting properties produced by their calcination, and they have not been in the market for a sufficient period of time to thoroughly determine their permanence and endurance. This, roughly speaking, is the history of the American Portland cement industry, which to-day gives employment to about 2,000 men, has 20 works, and manufactures about 800,000 barrels per annum.

From an engineering standpoint the question of the use of American Portland cement is naturally a serious one, inasmuch as the reputation of the engineer is measurably dependent upon the permanence and stability of the work he constructs. In this connection it is a satisfaction for the American manufacturer to be able to point to such records as will eliminate from the mind of every fair-minded engineer any questions he may have as to the character of the materials which established manufacturers in this country seek to have him use.

In the first place, let us consider what are the means of determining what a good Portland cement is, and what are the requirements generally adopted for the determination of such qualities. The first method is the testing for fineness and tensile strength. This testing may be for short or long periods, but the most convincing proof to the engineer, and far more conclusive than any of the ordinary seven and twenty-eight day tests that are usually used, and which in thousands of tests made by the best engineers show results equal to any foreign cement, is afforded by a table which will be found below, showing records on 300,000 barrels of American Portland cement, used on five of the most important pieces of work done in the United States, and carried out to a period of five years, showing continuous gains in the neat and sand tests made in the laboratory, and continuous gains in all the sand tests taken from the mortar boxes actually in use during the construction of the work. This table, which contains what is believed to be the only long-time records on Portland cement in the world for similar quantities and for as many different pieces of work, bears the most conclusive evidence as to the scientific side, as well as the practical side of testing Portland cement, and the results shown are certainly conclusive as to the reliability, permanence and stability of the American Portland cement, especially as the works on which the cement was used bear practical evidence to the same excellent qualities.

The second method of testing cement is by chemical analysis, to determine the constituents of the material and to ascertain whether it is properly proportioned, and whether it has an excess of the deleterious elements of sulphate of lime and magnesia. Analyses by such experts as Reid, Michaels, Redgrave, Candlot, and others, may be taken as standards of what the leading scientists think are about the requirements of a good Portland cement, and analyses of American Portland cements made by such experts as De Smedt, of Washington; Faija, of London; Booth, Garret & Blair, of Philadelphia, show that the American Portland cements, made in the standard way, compare favorably in all their elements with the analyses of the best foreign brands, as made by the best foreign experts. In conclusion, it may well be asked what the American manufacturer has to show, outside of chemical and scientific

Long-Time Tests.

Tests of over Three Hundred Thousand Barrels "Giant" Portland, on five of the largest dams in the United States; on the Niagara Falls Power-Tunnel, and the Reading Terminal Railroad and Station, in Philadelphia, for periods up to five years.

The only records of long-time tests on Portland Cement now published in the United States.

BRAND "Giant" Portland	Mode of Mixing.	1 Day		1 Week		1 Mo.		3 Mos.		6 Mos.		9 Mos.		1 Year		15 Mos.		18 Mos.		2 Years		3 Years		4 Years		5 Years		Fineness.		
		Number of Briquettes.	Average, in pounds.	Number of Briquettes.	Average, in pounds.	Number of Briquettes.	Average, in pounds.	Number of Briquettes.	Average, in pounds.	Number of Briquettes.	Average, in pounds.	Number of Briquettes.	Average, in pounds.	Number of Briquettes.	Average, in pounds.	Number of Briquettes.	Average, in pounds.	Number of Briquettes.	Average, in pounds.	Number of Briquettes.	Average, in pounds.	Number of Briquettes.	Average, in pounds.	Number of Briquettes.	Average, in pounds.	Number of Briquettes.	Average, in pounds.	Residue on No. 50 sieve, 2,500 holes to sq. in.	Residue on No. 74 sieve, 5,180 holes to sq. in.	Residue on No. 100 sieve, 10,000 holes to sq. in.
Sodom and Bog Brook Dams, New York Aqueduct. About 50,000 bbls.	Neat	1,025	140	1,398	348	220	422	180	540	100	631	30	638	180	682	30	687	110	672	110	694	90	736	60	771	10	840	......	......	18.0
	2 to 1	...	...	220	166	120	280	140	364	84	468	50	468	90	490	36	526	100	530	100	564	130	680	120	674	20	700			
	3 to 1	....	...	226	140	140	234	112	350	110	428	30	428	240	420	40	500	80	514	80	512	160	572	...	...	10	590			
Titicus Dam, New York Aqueduct. About 100,000 bbls.	Neat	3,448	157	4,165	380	637	476	505	529	478	575	479	599	350	642	181	594	135	584	137	611	62	668	...	...	...	...	......	......	11.7
	2 to 1	....	...	2,934	200	424	317	281	450	321	491	278	532	219	549	157	557	92	541	52	536	37	573							
	3 to 1	....	...	1,604	115	260	185	450	289	133	347	146	311	132	426	70	424	66	416	126	419	7	483							
Carmel and Craft's Dams, New York Aqueduct. About 40,000 bbls.	Neat	1,786	140	1,075	343	324	443	551	517	529	518	491	568	289	617	...	...	273	604	211	611	...	...	...	...	...	...	......	......	14.7
	2 to 1	....	...	1,642	182	216	308	85	445	87	480	76	472	43	585	...	...	49	477	55	475									
	2 to 1 from Mortar Box	....	...	61	164	51	237	8	385	11	494	8	491	7	367	...	...	12	516	3	568									
	3 to 1	....	...	13	100	13	174	7	319	12	372	11	398	10	413	...	...	8	401	10	406									
	3 to 1 from Mortar Box	....	...	45	112	31	166	6	310	8	480	7	500	9	541	...	...	7	437	5	406									
Reading Terminal Railroad and Station, Philadelphia. About 60,000 bbls.	Neat	....	...	329	315	267	376	69	451	15	549	16	576	10	523	1	640	...	...	...	...	...	...	...	...	...	...	.090	10.04	14.79
	3 to 1	....	...	536	79	431	129	104	174	20	228	15	225	47	261	5	287													
	2 to 1 from Mortar Box	....	...	190	84	180	144	17	219	13	234	25	281	62	325	12	417													
Niagara Falls Tunnel, Niagara Power Co. 60,000 bbls.	Neat	....	...	495	321	309	420	12	514	24	562	...	...	24	661	...	...	...	...	...	...	...	...	...	...	...	...	......	......	14.9
	2 to 1	....	...	482	152	271	242	54	369	20	454	...	...	7	472															
	3 to 1	....	...	527	98	399	177	143	254	181	301	...	...	12	391															

tests. It is true that he has shown that his cement meets all the requirements of fineness and tensile strain; that it analyzes the same as the best foreign brands; but this is not all that should be properly asked of it. He should show where his cement has been used, and, therefore, as the "proof of the pudding is in the eating of it," the American manufacturer is enabled to point to the engineer as evidence of the character and stability of his product to the fact that it has been used on such important work as the Eads Jetties at New Orleans; the Cornell, Sodom, Bog Brook, Craft's, Carmel and Purdy's dams of the New York aqueduct system; on all the dams of the great East Jersey water system; on all the dams of the Scranton Water Co. system; on the St. Louis Water Works; on the Chicago Elevated Railway; on Government Post Office buildings at Washington, Buffalo, and other cities in the United States; on the Manhattan Life Building, Waldorf Hotel, Germania and Hanover Fire Insurance buildings, Wool Exchange, Coffee Exchange, and other large buildings in New York; on the Drexel Building, Drexel Institute, Harrison Buildings, Odd Fellows Temple, Girard Estate Buildings, Girard Trust Co. Building, Williamson School, House of Refuge, and other large buildings in Philadelphia; on the large new East River Bridge and Third Avenue Bridge, New York; on the New London bridge, over Thames River, Conn.; the celebrated Johnstown Bridge of the Penna. R. R.; new Delaware River bridge of the Penna. R. R.; and on many small bridges of the Pennsylvania, Philadelphia & Reading, Lehigh Valley, Baltimore & Ohio, Delaware, Lackawanna & Western, and New York Central Railroads; on the great East River Gas Tunnel, New York; on all the work of tunnels, power-house and other buildings of the Cataract Construction Co., at Niagara Falls; on the Niagara Power Co., Niagara Falls, N. Y.; on the cable and underground electric roads in Pittsburg, New York and Philadelphia; on the Jersey City Terminal and Station, Jersey City; and on the bridges, approaches and new Broad Street Terminal and Station of the Pennsylvania Railroad, Philadelphia; on the Terminal and Station of the Philadelphia & Reading R. R., Philadelphia; on the Allentown and Easton, and other stations of the Lehigh Valley R. R. and Philadelphia Station of the Baltimore and Ohio R. R. It is on evidence such as this that the American Portland cement manufacturer, with his works, capital and labor in this country, bases his claim to the consideration of engineers, and points to as proof of the progress of the Portland cement industry in the United States.

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STRENGTH OF BRONZE IN COMPRESSION.

BY S. BENT RUSSELL, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read before the Club, October 16, 1895.*]

IN certain kinds of machinery, where the wearing parts are exposed to conditions which would cause corrosion of iron or steel, the engineer often finds it economical to make these parts of bronze, or to line them with bronze or other alloy. This is especially the case where the mechanism has periods of idleness while the parts are exposed to the corroding conditions.

A good example of such machinery will be found in sluice gates, water and steam valves, etc. Such gates and valves are frequently operated by screws, and it was the designing of such screws and similar members which led to the tests herein given. The writer has at times had occasion to design gate stems over 3 inches in diameter, and others having a travel of as much as 6 feet.

Now, in designing a screw stem to be operated by hand-power, it is desirable to make the diameter as small as may be, so as to reduce the friction to a minimum.

The work in foot pounds needed to overcome the friction of the thread under a given load and with a given "pitch," is in direct proportion to the distance through which the thread has to travel. This

* Manuscript received December 13, 1895.—*Secretary, Ass'n of Eng. Socs.*

distance is, of course, proportional to the diameter of the screw. Hence, as stated above, the smaller the screw the more easily it will be operated.

In the case of piston rods too, smaller diameters make smaller stuffing boxes and less friction. Moreover, bronze is very expensive compared with iron, so that true economy calls for careful designing. Gate stems and piston rods, when properly designed, will fail in compression rather than in tension. What the designer needs, then, is a rule or rules for finding the strength of bronze columns. On the other hand, while many tests of bronzes in tension have been made and published, very little study appears to have been given to the strength of bronze in compression.

TABLE I.

TENSION TESTS OF BRONZE.

	Laboratory Number.	Diameter.	Breaking Strength in Pounds per Square Inch.	Proximate Elastic Limit, Pounds per Square Inch.	Per cent. of Elongation.	Per cent. of Reduction of Area.	Modulus of Elasticity in Pounds per Square Inch.
Tobin Bronze . .	486*	1.250	66180	53000	36.3 in 4 inches		
" . .	487†	1.049	68880	. . .	. . . .	22.9	
" . .	490	0.872	62480	49400	31.2 in 6 inches	44.4	
" . .	520	0.869	63200	. . .	31.0 "	44.2	14170000
Phosphor Bronze .	488	1.000	28540	15900	12.7 "	20.1	
" .	521	1.000	28090	. . .	14.0 "	15.9	10510000
No. 85 Composition	489	1.000	30060	12000	12.0 "	19.1	
"	519	1.000	30060	. . .	11.5 "	16.4	10700000

* Broke in grip.
† Stud bolt with thread and nuts.

Enough has been said, however, to show the reasons for making the tests herein described, and to justify the writer in publishing this article.

Consulting well-known authorities we learn that to arrive at the strength of a column we must have the compressive *strength of the material*, and also the elastic limit and modulus of elasticity. In long columns the rigidity of the material is a very important factor.

Not being satisfied with the data obtainable in books of reference, the writer was impelled to order the tests herein described.

Three kinds of bronze are now in general use by the Water Works Department of St. Louis, viz.:

Tobin bronze, which comes in rolled rods. Phosphor bronze, which may be cast in any form. And thirdly, a composition, made of 85 parts of copper, 10 parts of tin, and 5 parts of zinc, which also may be cast in any form.

To prepare for the tests, 11 or 12 test-bars of each kind of metal were obtained. To show the quality of the metal by ordinary stand-

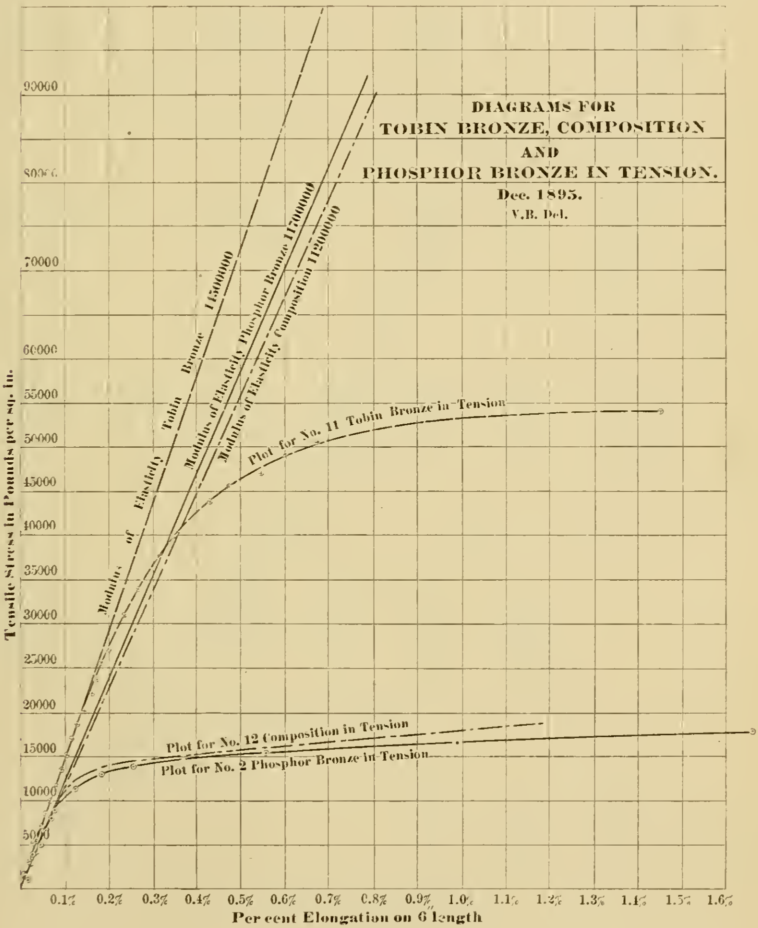

Fig. 1.

ards, two bars of each kind were turned down for tension tests, and the strength and elasticity of the metal in tension were determined, and also the ductility and reduction of area.

The remaining test-bars which were all $1\frac{1}{4}$ inches in diameter and 15 inches long, were tested in compression to failure. The Tobin bronze

TABLE II.

SUMMARY OF TESTS OF BRONZE BARS.

Kind of Bronze.	Kind of Stress.		Number of Tests.	Ultimate Strength in Pounds per Square Inch. f.	Number of Tests.	Proximate Elastic Limit, Pounds per Square Inch.	Number of Tests.	True Elastic Limit, Pounds per Square Inch. p_o.	Number of Tests.	Modulus of Elasticity, Pounds per Square Inch. E.
Tobin Bronze.	Tension.	Maximum.		63200						
		Minimum.		62480						
		Average.	2	62840	1	49400	1	20200	1	14170000
	Compression.	Maximum.		43760		40800		13880		15410000
		Minimum.		40820		33400		12240		15020000
		Average.	9	42520	7	36210	2	13060	2	15215000
Phosphor Bronze.	Tension.	Maximum.		28540						
		Minimum.		28090						
		Average.	2	28315	1	15900	1	8900	1	10510000
	Compression.	Maximum.		19100		17100		8800		14200000
		Minimum.		17710		16700		8600		13980000
		Average.	10	18360	8	17000	2	8700	2	14090000
No. 85 Composition.	Tension.	Maximum.		30060						
		Minimum.		30060						
		Average.	2	30060	1	15300	1	11500	1	10700000
	Compression.	Maximum.		18450		16300		9800		12410000
		Minimum.		17630		15500		9400		11760000
		Average.	9	18070	7	15950	2	9600	2	12085000

samples were simply cut from rolled 1¼ inch rods, while the others were cast and turned down to 1¼ inch; all were cylindrical, with flat ends.

Two compression bars of each metal were tested carefully with an extensometer, so as to obtain a strain diagram.

Table I shows the results of the tension tests, and this table, with

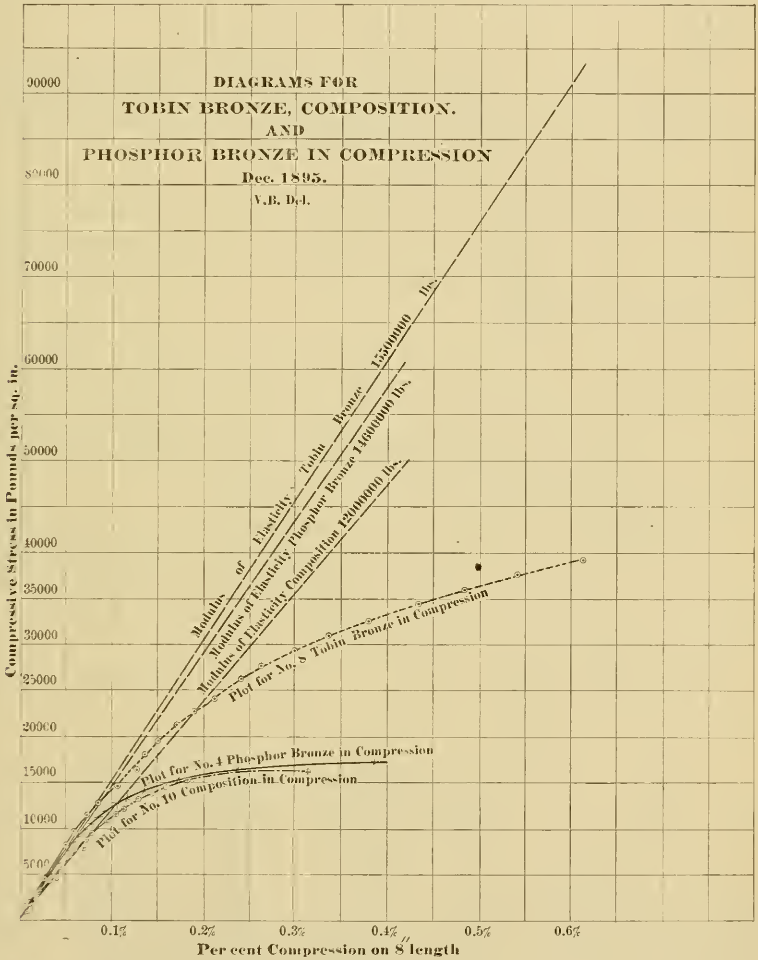

FIG. 2.

the strain diagrams shown on Figure 1, gives a complete report of the tests made in tension.

Table II gives a summary of all the tests of the three metals, both in compression and tension, and is, we may say, the important feature of this paper.

In both of the above tables, the writer has used the expression "prox. elastic limit," to signify the point at which the stretch or compression of the bar can be observed with the dividers. This point has been known as the "elastic limit" by some, and has been termed the "yield point" by others, to distinguish it from the true elastic limits which in many materials can only be determined by a study of the strain diagram.

Figure 2 gives one strain diagram of each metal in compression. In each case, the two diagrams of the same metal were practically identical, hence, to reproduce them all would add nothing to the reader's profit. A glance at this plate will give a good idea of what difference there is in the nature of the three metals.

As these bars were only 12 diameters in length, and had flat ends, they may fairly be considered as short columns. The results obtained directly from these tests may be used for short columns, and will probably be of value to the designer.

The reader will note the difference between these strain diagrams and those given by wrought iron and steel which show a well-defined yield point. It is noteworthy too that the difference between the slope of the line at the true elastic limit and the slope at, or rather just below the "prox. elastic limit," is more marked in the case of these alloys than it is in the wrought iron or steel strain diagram.

In connection with the observed facts herein described it was thought proper to furnish some deductions showing the strength of long columns of bronze. In the absence of direct experiments on long columns the designer must be content with the probable values obtained by the use of more or less rational formulas.

For very long columns the maximum load can be definitely determined by the use of Euler's rational formula.*

$$p = \frac{\pi^2 E}{\left(\frac{l}{r}\right)^2}$$

When $p =$ safe load of column in lbs. per sq. in.

$E =$ modulus of elasticity in lbs. per sq. in.

$\frac{l}{r} =$ length of column divided by least radius of gyration.

Plotting the maximum load and the $\frac{l}{r}$ as co-ordinates we obtain a curve which is applicable whenever the maximum load per square inch of section falls below the true elastic limit of the material.

We now know the strength of short columns and the strength of very long columns. It only remains to find the strength of columns of medium length.

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* All columns are assumed to be symmetrical in cross-section and symmetrically loaded.

To do this the writer has made use of a modification of the well-known Gordon formula so as to obtain a curve which would agree with Euler's formula at the true elastic limit, and would agree with the observed strength of short columns when $\frac{l}{r} = 0$.

TABLE III.

BRONZE COLUMNS—FLAT ENDS.

Data used in computing Table IV.

	Ultimate Strength, Pounds per Square Inch. *f.*	True Elastic Limit. *po.*	Modulus of Elasticity. *E.*
Tobin	42500	13000	15000000
Phosphor	18000	9000	14000000
No. 85 Composition	18000	9500	12000000

TABLE IV.

ULTIMATE STRENGTH OF BRONZE COLUMNS WITH SYMMETRICAL SECTIONS AND SYMMETRICAL LOADING.

Flat Ends.	*p.* Pounds per Square Inch.			Pivoted Ends.	Cylindrical Columns with Circular Cross-Sections. $\frac{l}{d}$*	
$\frac{l}{r}$	Tobin.	Phosphor.	No. 85 Composition.	$\frac{l}{r}$	Flat Ends.	Pivoted Ends.
1	2	3	4	5	6	7
24	42400	18000	18000	12.	6.	3.
40	41800	17900	17900	20.	10.	5.
48	41400	17900	17900	24.	12.	6.
56	40700	17800	17800	28.	14.	7.
64	39900	17700	17600	32.	16.	8.
80	37700	17400	17300	40.	20.	10.
106	32800	16700	16400	53.	26 50	13.25
120	29700	16200	15800	60.	30.	15.
140	25300	15300	14700	70.	35.	17.50
160	21100	14200	13500	80.	40.	20.
180	17400	13000	12200	90.	45.	22.50
200	14200	11800	10900	100.	50.	25.
213	12500	11000	10100	106.50	53.25	26.60
223	11300	10400	9500	111.50	55.75	27.90
248	8870	9000	8070	124.	62.	31.
280	6580	7380	6500	140.	70.	35.
300	5510	6500	5660	150.	75.	37.50

* $\frac{l}{d}$ = length measured in diameters.

It is not necessary here to go into a mathematical discussion on column formulas. There is, however, a way of testing such a curve mathematically which will show it to be near enough to the ideal curve for all practical purposes.

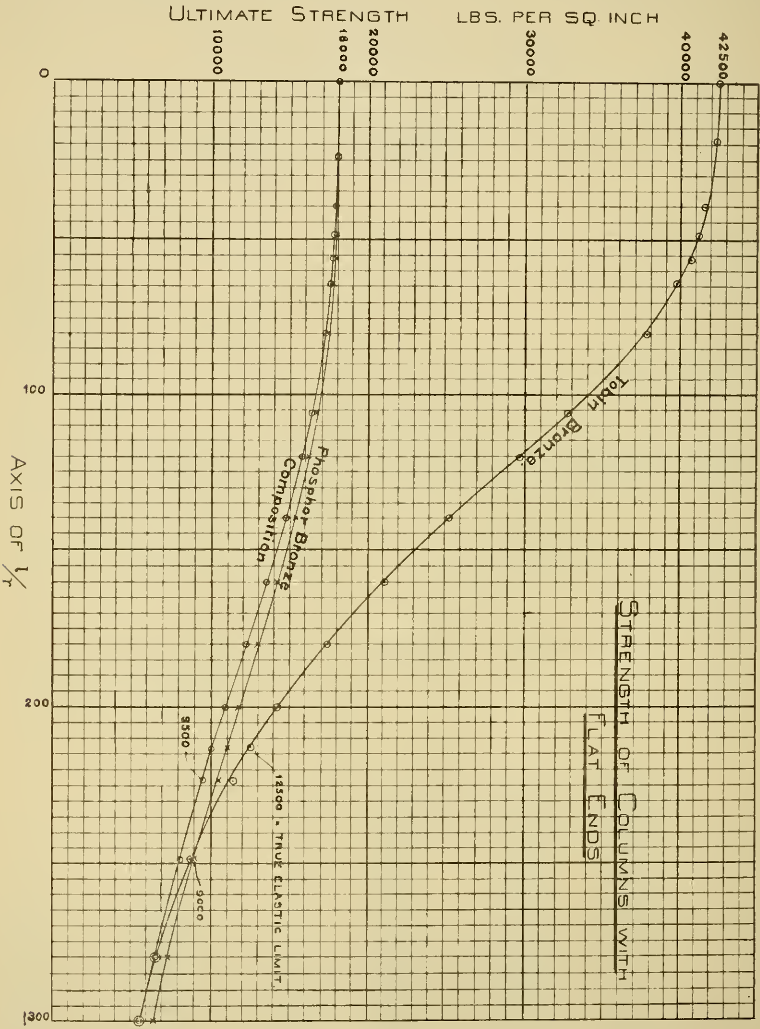

FIG. 3.

From such formulas the values given in columns 2, 3 and 4 of Table IV were computed, using the data shown in Table III. Plotting the values of p obtained from the formulas to the corresponding values of

the ratio $\frac{l}{r}$ we get the curves shown on Figure 3. The strength of a column with pivoted ends may be taken as equal to the strength of a flat-end column having twice the length.

In using the diagram (Figure 3) and Table IV, the designer should of course keep in mind that the values given are obtained by deduction from the strength and elasticity of short columns, and should use whatever factor of safety his judgment dictates. In the case of the Tobin bronze it is well to remember also that smaller rods require more rolling and are usually tougher than large rods.

It is interesting to note from the diagrams and tables that short columns of Tobin bronze are much superior to similar columns of the other metals. For very long columns, however, the metals show nearly equal strength.

The principal value in the deductions herein given comes from the fact that they are based on experiments with true short columns, and not on the crushing strength of cubical or nearly cubical specimens.* Figure 4 is given herewith to show the shape after testing of the small columns used in the experiments.

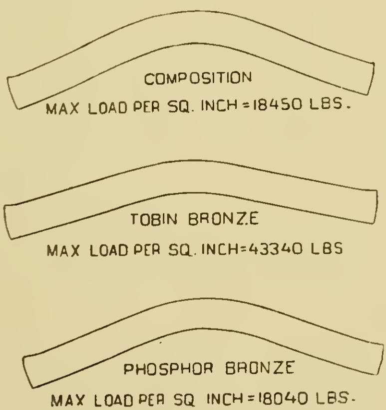

FIG. 4.

* In the discussion of the paper Prof. J. B. Johnson called attention to the fact that the crushing strength of a specimen nearly cubical in form, of metal like bronze, copper or lead, is in reality indeterminate, as the material will flow without true crushing.

THE PRESENT EUROPEAN PRACTICE IN REGARD TO SEWAGE DISPOSAL.

By Allen Hazen, Member of the Boston Society of Civil Engineers.

[Read before the Society, October 16, 1895.*]

The countries of western and central Europe have a denser population than is the case with the greater part of the United States, and although their cities are growing, in many cases, almost as rapidly as ours, there have been for many years in Europe centers of population which compelled attention to various sanitary questions long before corresponding issues were raised in the United States, and processes of sewage purification have been in common use in Europe, particularly in England, for the last quarter of a century, which are just beginning to be seriously considered and adopted in the United States.

It is of course true that a certain amount of work, particularly experimental work, has been done in the United States which is of as high a grade as that which has been done anywhere, and some of the information which has been secured in America in regard to sewage purification processes, and the disposal of sewage by dilution in streams and lakes, is of great value to us and could not be replaced by any amount of European experience obtained under other conditions of climate and geology; but on the other hand, the continued experience of European cities for a long series of years with many of the problems which are now seriously confronting American cities has resulted in the accumulation of a fund of information which deserves to be most carefully studied by all who would be proficient in the art and science of sewage disposal.

There are in reality two sewage disposal problems which are radically different from each other in their natures and which present themselves in different cases. The first of these is the case of the discharge of sewage into bodies of water, either lakes or rivers, from which water is taken for domestic supply from points which may be reached by the discharged sewage. The problem presented in this case is to so completely purify the sewage that when mixed with the water it will not be injurious to health. Years ago, before the germ theory of disease was established, the possibility of purifying sewage in this way would hardly have been admitted, but thanks to the more recent German and English investigations, as well as to the experiments of our own [Mass.] State

* Manuscript received December 24, 1895.—*Secretary, Ass'n of Eng. Socs.*

Board of Health, it is now well known that it is entirely possible to accomplish this through the wonderful purifying power of sandy soils under proper conditions; and it is actually a fact that the effluents from certain European sewage works, as well as from some of the purification fields in Massachusetts, are preferable, from a hygienic standpoint, to the public supplies of a number of large American cities.

The second problem in sewage purification is that of so purifying sewage that it will not cause a nuisance in the water into which it flows. When a small quantity of sewage is discharged into a large volume of pure, or comparatively pure water, the organic and polluting matters of the sewage are oxidized and destroyed by the oxygen of the air which is ordinarily contained in solution in the water into which the sewage is discharged. In case, however, the quantity of sewage becomes greater than can be oxidized at once by this oxygen, the last part of the decomposition of the organic matters takes place in the absence of air, and with the formation of products which are given off into the air causing objectionable odors, and the whole body of the liquid becomes foul. The condition becomes still worse when the water is still, or has so low a velocity that it allows the heavier matters from the sewage to be deposited upon the bottom, where they accumulate as masses of mud which decompose with the most objectionable results. This condition of affairs may often result even though the quantity of sewage is not great enough to render the whole body of the water offensive, and is thus likely to occur in sluggish streams which would otherwise remove the sewage without nuisance.

It is undoubtedly a fact that sewage has been purified much more frequently to prevent the production of a nuisance of this kind than to protect the purity of drinking water supplies, perhaps because a black dirty stream, giving off sulphureted hydrogen gas, is more obviously a nuisance than is a polluted water supply, the relation of which to the health of the community is too often but imperfectly realized even by those having such matters in direct charge, and much less by the mass of voters and tax-payers whose support must be obtained before any expensive improvements are possible.

The processes which are used for purifying sewage may be divided into two general classes: land treatment and chemical processes, although a combination of both of them is frequently used. The principles involved in purifying sewage by applying it to land, are essentially the same whether it is applied to soils and loams at a very low rate and with a growth of crops under the name of "broad irrigation," or whether it is applied to specially prepared areas of favorable materials at much higher rates under the name of "intermitting filtration;" and even the filtration at very high rates with forced ventilation, which has recently

been proposed, but has not as yet been carried out on a large scale, involves exactly the same principles.

The other class of processes are those which by chemical and mechanical means attempt to remove from the sewage in concentrate form a portion of its impurities, and although the number of processes which might be included in this general definition is very great, none of them have achieved practical succcss except such as can properly be called "chemical precipitation."

One of the most interesting cases where sewage is purified to prevent the pollution of public water supplies, is furnished by the cities and towns upon the watersheds from which the water supply of London is drawn. Conservancy Boards have control of the rivers, and it is their duty to see that they are not polluted so as to affect the quality of the water supplies drawn from them, or become otherwise injurious to the people upon their banks. The Conservancy Board of the River Thames has control of the main river for its whole length, and of its tributaries within ten miles of the main river measured in a straight line, but curiously enough, it has no control of the tributaries beyond that distance. The Conservators of the River Lea have control of the entire watershed.

There are thirty-nine places upon these two rivers which are giving their sewage systematic treatment, and, so far as known, no crude sewage is ordinarily discharged into the rivers at any point. Of these thirty-nine places, thirty-eight treat their sewage by applying it to land, while one of the smaller places, Hertford, uses chemical precipitation. The Conservators do not regard the chemical precipitation as satisfactory, and have recently conducted an expensive lawsuit against the local authorities to compel them to further treat their effluent, but this suit was lost, as the court held that no actual injury to health had been shown. It is worth noticing, however, that the water into which the effluent is discharged, is all carefully filtered before it is delivered to consumers.

The Conservators require, where land treatment is used, that sufficient area shall be provided to allow all of the sewage to percolate through it in ordinary weather, and they strongly object to allowing any sewage to flow over the surface of the land into the streams. The land used for this purpose, however, is, as a rule, much less porous than the land commonly used for sewage treatment on Continental Europe and in this country; and at times of heavy storms there is often as much water from the rain alone as the land can take without becoming unduly flooded, and it is then incapable of receiving even the ordinary quantity of sewage, and much less the storm flow, as the sewers are generally, if not always, on the combined system. At such times, the

sewage either flows over the surface of the land with the very inadequate purification due to the retention of solid matter in the grass and osiers, or perhaps more frequently it is discharged directly into the rivers without even a pretense of treatment. The Conservators apparently regard this as an unavoidable evil and do not vigorously oppose it, as it is their theory that at these times the increased dilution with the high water in the rivers is such that there is no great danger from the sewage, although it would seem that the increased velocity and consequent reduction in time for the matters to reach the water-works intakes would, in a large measure, counterbalance the increased dilution.

The water companies are expected to have so much storage capacity for unfiltered water that they will not be obliged to take in water at times of flood; but as a matter of fact, it is believed that they often do take in water at these times, although no records are kept either of the times when water is taken in, or of the times when the sewage is discharged without treatment. This is one of the cases which one so often finds in England and elsewhere, where it is regarded as safer to have no information than to keep records. It should be said, however, that no evidence has been found that the health of the inhabitants of London is in any way affected by this discharge of sewage into the water courses from which their water is drawn; but this favorable condition is believed to be largely due to the great care with which all of the water is filtered.

The cases of the other class where sewage is purified to prevent its becoming a nuisance, but without regard to possible pollutions of water supplies, are very numerous. Many years ago England took the lead in works of this nature, and has at the present time probably a larger number of works than are to be found in all the rest of the world.

England has a very dense population, but it is far from being equally distributed over its entire area Near the southeast corner, on the tidal estuary of the Thames, is that enormous aggregate of population known as "Greater London;" and in central England, directly back of England's greatest harbor, Liverpool, is a small area which has become perhaps the most densely populated of any region of its size on the face of the earth, due to the harbor and to the deposits of coal and iron ore which there occur. Within a distance of forty miles from Manchester are Liverpool, Salford, Bolton, Preston, Oldham, Blackburn, Huddersfield, Birkenhead, Leeds and Sheffield, all of them great cities, and a hundred smaller places which so completely fill the intervening spaces that parts of the region have almost the aspect of one great extended city. A large part of the area is a broken hilly country, with steep, although not high hillsides, between which are narrow valleys in which are the railroads, mines and factories. The rivers, as they are called, are but short streams rising in the hills immediately back of the

cities, and many of them would hardly be dignified with the name of river in this country.

With the great development of manufacturing, the sewage and wastes were at first discharged directly into the streams until they became excessively foul, and the sewage problem was forced upon them in perhaps its most difficult form. There were but limited areas of land in the valleys with elevations which would allow their use for sewage purification, and even these areas were often occupied by mills, or held at high prices in expectation of such use, and the land itself was, as a rule, compact, impervious and but poorly adapted to sewage purification. The conditions in this region were probably more favorable for chemical precipitation, as against land treatment, than at almost any other place, and chemical precipitation has been the most commonly used method of treatment, Leeds, Sheffield, Bradford, Manchester, Salford and Huddersfield among the larger places using it. Chemical precipitation, however, although great improvements have been made in the form of settling tanks and in the methods of managing them, removes scarcely more than one-half of the organic matters in the sewage and never more than two-thirds, and the effluents generally carry on an average from two to five parts per hundred thousand of suspended matters capable of forming deposits in the streams; and it has been found that effluents purified to only this extent are very apt to produce more or less trouble when discharged into such small streams as exist in this region, and it is becoming more and more apparent that some more thorough process will be required before the problem can fairly be considered solved.

Already much has been done in this direction. At Sheffield the effluent is taken through coke filters at a very high rate, and a portion of the suspended matters in the effluent is thus removed, although the purification obtained is far from what might be desired. This use of coke for filtering material has this strong point in its favor, that when the coke becomes dirty it can be burned with the matters accumulated in it under the boilers that are sure to be in use at the works. At Huddersfield, the effluent is filtered through sand and a patented substance called "polarite," with the result that most of the suspended matters are removed, although the dissolved organic matters hardly have time to become oxidized with the rapid filtration employed.

At Bradford and at Salford experiments have been made on a considerable scale with rapid filtration through sand or coke, and forced aeration has also been experimented with in the endeavor to find a process which is at once very rapid and capable of yielding effluents comparable in purity to those obtained from land treatments. This question of further purification for chemical precipitation effluents is now being everywhere discussed, and experimental filters are to be found with a

surprising frequency, and we may confidently expect that the coming years will witness great changes in the methods of sewage treatment in this locality.

A little to the south of the Manchester district is Birmingham, a great manufacturing city, which treats its sewage first by chemical precipitation, and afterwards applies the effluent to a large area of meadow land on both sides of the small river into which it eventually finds its way. Leicester, a few miles to the east, uses substantially the same process.

At London the sewers from a large metropolitan district have been gradually combined into one great system, or rather two systems, one for the north and one for the south side of the River Thames, both of which are administered by the London County Council. The conditions here are in many respects different from those of almost any other large city. The sewage is carried down by intercepting sewers to points some miles below the city, and is discharged into the estuary where there are very powerful tidal currents in addition to the natural flow of fresh water from the river. Formerly the sewage was discharged without treatment at these points, but it caused so great a nuisance in the river, both to the shipping and to the residents upon the banks of the river, both below and above the points of discharge, that in the last years works have been built to treat the whole of it by chemical precipitation, except the storm overflows.

Although London is noted for its rainy weather, it seldom rains rapidly there, and the precipitation is more apt to come in the form of a slow drizzle, which the sewers are capable of removing, and the sewage which goes to the river through the overflows is much less than would be the case in an American climate. Mr. Santo Crimp, formerly in charge of the London Sewerage Works, has estimated that in the aggregate only about 4 per cent. of the sewage is discharged untreated into the river, the remaining 96 per cent. being treated before its discharge.

On Continental Europe the conditions for land treatment are, as a rule, more favorable than is the case in England, and chemical precipitation has gained but a slight foothold, only one large city, Frankfort-on-Main in Germany, employing it, although it is used at a considerable number of smaller places and is being considered at Leipsic.

In the early days of chemical precipitation lime was commonly employed as a precipitant, and where the sewage contains a large amount of iron and acid from wire works, as is the case at Leeds, Sheffield and Birmingham, lime answers as well or better than any other precipitant, but in other cases it has little to recommend it, and has usually been superseded either by copperas or by sulphate of alumina, although it is necessary to use with each of them a small quantity of

lime to insure rapid precipitation. At London copperas is employed, while other English cities have varied their precipitants from time to time.

One of the serious problems connected with chemical precipitation of sewage is the disposal of sludge, and in selecting the precipitant it is necessary to consider not only the purity of the effluent which can be obtained, but also the quantity and character of the sludge produced by it. At London several tank ships are employed which carry the sludge out to sea, each ship making two trips daily and carrying about 1,000 tons, of which 90 per cent. is moisture. To reduce the sludge to as small a volume as possible, it is pumped from the settling tanks into another set of smaller tanks and is settled over again, reducing it to one third of its original volume. From these the supernatant liquid flows back into the incoming sewage to be treated over again, and the remaining sludge is run into the tank ships. These ships are of steel and have air chambers in their bottoms to give them sufficient buoyancy so that the sludge will flow out through the openings in their bottoms when they reach the point of discharge, fifty miles from the works.

At Birmingham the sludge is run upon and dug into several hundred acres of land with fairly good results. At Sheffield and other places it is simply piled up on unused land and given away for a fertilizer when possible, and by sprinkling it with lime and with chloride of lime in summer, it does not become an unbearable nuisance, although this practice can hardly be recommended. Manchester and Salford have hoped to carry their sewage out to sea, as is done at London by means of the Manchester ship canal, but I do not know that they have yet commenced to do so.

Huddersfield and many of the newer works press the sludge in filter presses to solid cakes which can be easily handled and which can be applied to land or stored without creating a nuisance. The putrefaction, which makes sewage and sludge offensive, seems to require the presence of an excess of moisture, and when the moisture is absent, as in pressed sludge and in land used for sewage treatment, this putrefaction did not occur, but the changes which take place are of an inoffensive nature. The cost of pressing is considerable, and it is this which probably prevents it from being more generally adopted.

The shape of the settling tanks for chemical precipitation has been changed somewhat in the course of years. The earlier tanks were nearly square and were often used intermittingly, being filled with sewage, allowed to stand and afterwards emptied and then filled up again. This was known as the intermittent process and has been almost everywhere abandoned, although still in use at Sheffield. In the continuous process, now generally used, the tanks are connected with each

other and the treated sewage is run into a series of them, passing from one to another until finally it is discharged. The newer works, however, as a rule consist of long narrow tanks so arranged that a portion of the treated sewage passes through each of them and is then discharged, so that each tank is entirely independent of the others. These tanks are ordinarily from 30 to 60 feet wide, but are occasionally much wider, and in length range from one or two hundred to six and ten hundred feet. The bottoms slope rapidly from each side to the midde, and the middle slopes slightly from the outlet end of the tank toward the inlet, and there is usually a sludge channel in the middle a foot lower than the bottom, to insure a rapid removal of the sludge when the tanks are cleaned. All of the earlier tanks were open to the sky, but in 1884 Lindley built precipitation tanks at Frankfort covered with a vaulting with soil above, laid out as a garden. This arrangement prevents any possible interference with the sedimentation by the wind or by ice, and also makes a much more attractive appearing place than the open tanks.

The settling tanks at London are also vaulted. On the north side of the river the tanks are only 32 feet wide, and there is an arched spandrel wall half way between the sides, and the roof is made of two continuous arches covered with earth and with manholes to furnish light. It is stated that it was quite as cheap to build the tanks in this way as it would have been to build them open, because the walls between the tanks, being supported at the top, are very much thinner than would have been necessary with open tanks, and the excavated material was placed above the vaulting without expense for removing it, and the economies thus affected fully equaled the cost of the vaulting. The more recently constructed settling tanks on the south side of the river are of the same general construction, but the manholes were omitted, and it is found that there was both a great saving in the cost of construction, and the work of cleaning the tanks can be better done by artificial light throughout than by the very irregular light admitted through manholes.

Vertical settling tanks like those used at the World's Columbian Exposition at Chicago are occasionally used in Germany, particularly in small places, and are in some respects convenient, although the sedimentation is probably less complete than is the case with properly constructed horizontal tanks. The famous tanks at Dortmund are being replaced by broad irrigation.

In other parts of England, where the population is much less dense than in the districts mentioned and where land for sewage treatment is more easily secured, chemical precipitation works are the exception rather than the rule, and sewage farming is generally employed where sewage requires to be treated.

On the continent, Paris first adopted land treatment for sewage, many years ago, but selected an area quite near the city and which was only large enough to receive a portion of her sewage. The process was entirely satisfactory as far as purification was concerned. No nuisance was created, and some return was obtained from the crops on the capital invested. There was, however, no land suitable and convenient for treating the remainder of the sewage without going some miles further down the river, and for many years the system was not extended.

In the seventies, Berlin took the matter up and adopted substantially the same system which was then in use at Paris, and has since extended it from time to time until for many years all of the sewage of Berlin has been treated. Berlin with its immediate suburbs has, at the present time, a population of nearly two millions, and is growing almost as fast as Chicago, but the population is very compact, and the surrounding country for many miles consists of sandy land in every way suitable for sewage treatment, but too poor to repay ordinary cultivation. Under these circumstances, there has been no object in economizing in the area of land used, and the city has taken large areas of land and is extending the mains to irrigate as large an area, as possible with sewage. In 1893, 10,800 acres were in use receiving on an average 4,100 gallons per acre daily. The sewage is all pumped and treated, except when in thunder storms more rain falls than can be carried by the sewers. The Spree flowing through the heart of the city is said to have been as dirty as the Chicago River is at the present time before the works were commenced, but it has been so thoroughly cleansed that one would hardly suspect it of having once been polluted by sewage. The irrigated land is cultivated with some profit to the city, and in good years, 2 per cent. net profits on the capital of about $6,000,000 have been earned.

After Berlin adopted land treatment for her sewage, Dantzig and Breslau adopted substantially the same process, and more recently Magdeburg has been preparing land to be used in the same way, while Cologne, Hanover and other cities are talking of doing so.

The German cities, as a rule, are situated upon much larger rivers than are the English cities, and sewage disposal has not been so pressing a problem with them; but on the other hand the conditions for disposing of the sewage upon land are much more favorable than in England, and the expense of carrying out the process is less; and now that the process has been demonstrated by many years' trial in the three cities mentioned to be a practical success, the Imperial Board of Health, which has great power in these matters, is insisting upon the adoption of sewage purification in almost all cases where important extensions or changes in the sewerage systems are adopted. As everywhere else, it is

difficult to prevent a city which has been discharging its sewage into a river from continuing to do so, particularly where the river is large enough so that no great nuisance is caused. But when a city wishes to extend its sewerage system, or increase the size of its sewers, and the project is sent to Berlin for examination and approval, then the Board can take the position that the sewage should be purified, and it usually does so.

Some of the leading officials in Berlin having charge of the German rivers were of the opinion that all sewage should be treated without regard to the size of the rivers into which it is discharged, although a number of the rivers, such as the Rhine, the Elbe and the Oder, are so large that from our standpoint it is hardly possible to conceive of any appreciably injurious results from the discharge of sewage into them.

The soils used for sewage purification in Germany are invariably sandy, pervious materials, and the natural surface of the ground is so nearly level that it can be developed with a minimum of expense. The areas are usually divided into separate beds by low earth embankments, quite similar to those at Framingham and Marlborough in this State. The surface of these beds is always cultivated, grass, beets, cabbages, wheat, rye, oats and apple-trees being the leading crops. Wheat and oats when they are irrigated grow very rankly, and as the farmers say, run to straw, and good crops are seldom obtained. Our American corn or maize cannot be successfully grown, because the summers, and particularly the summer nights, are not warm enough, and the grain will not ripen.

Germany is some degrees farther north than New England and the winters are of about the same severity, but the winter nights are much longer and the days shorter, and it thus happens that in the darker months of the year it is impossible to distribute all, or even the greater part, of the sewage over the land by daylight, and it is found that however carefully instructions are given, the men having the distribution in charge will not properly perform their work at night. To provide for this contingency, certain areas are set apart upon all the German farms having substantially level surfaces and surrounded by embankments much higher than the ordinary embankments, that is 8 to 10 feet high. The areas are also much greater, often containing 10 or 20 acres in one lot. During the long dark nights of the fall and winter, sewage is run into these basins, often filling them several feet deep. Of course little purification takes place under these circumstances, but owing to the cold weather, the sewage is retained pretty nearly in its original condition, or at least without offensive decompositions, generally covered with an ice sheet during the winter.

As soon as the days become longer, in early spring, all of the

sewage is again applied to the land and these basins are no longer used. The ice melts and the pond of sewage soaks away in the course of a few weeks, and the surface of the land covered with the organic matters which have been strained from the sewage, is exposed to the air and becomes dry, and soon afterwards it is ploughed under, and the matters are destroyed, as in the ordinary process of intermittent filtration. Wheat and oats can be raised in these basins in the summer, and good crops are obtained. No sewage is ever put upon them except in winter.

Paris has for many years treated a portion of her sewage as mentioned above, by intermittent filtration upon the sandy soil of about 2,000 acres of land, nearly surrounded by one of the broad bends in the River Seine, just below the city. The sewage has been pumped to this land from the main outfall sewer as needed by the crops, and when the crops did not require it, the sewage has been discharged untreated into the river. In recent years, only about 20 per cent. of the sewage has been treated ; in rainy weather and winter a much smaller proportion, while at dry seasons a larger quantity was taken.

The condition of the River Seine, below the point of discharge of the sewage, has become extremely foul, and the city has recently voted to construct an outfall sewer down to another and larger area of land in the next bend of the river below that now used, and to treat the rest of its sewage there. This outfall sewer involves the construction of three siphons under the Seine, and the purchase of 25,000 acres of land, which will give the city an ample area upon which to purify all of its sewage. The estimated cost of this work is $6,000,000.

At Paris, as in the English sewage farms, the embankments between the beds are a much less conspicuous feature, and one of the most common methods of applying sewage is to have the land in ridges and furrows, the sewage being turned into the furrows, while vegetables and other crops are raised upon the ridges which are never covered by the sewage. Of course it is necessary at certain points to have embankments to prevent the sewage from running over the surface into the river, but these are reduced to a minimum.

There are some unusually interesting sewage disposal problems in some of the Dutch cities. Rotterdam is situated upon the Maas, which is really the main outlet of the River Rhine, with its enormous flow from the mountains in the south of Germany and in France and Switzerland, and in addition there are strong tidal currents, so that the city has no difficulty in disposing of its sewage. Amsterdam and The Hague, however, are not situated upon rivers, but only upon the intricate system of canals which intersects a large part of Holland. Streets, as a rule, are three or four feet higher than the water in the canals, and the houses are built upon foundations about even with the streets, and there

are no cellars. There is often a canal between every two streets, and in the few cases where it is omitted, it is in any case but a short distance from any part of the city to some canal. It has been the custom ever since the memory of man to discharge all sewage, garbage and other wastes into the canals direct. This has resulted in the canals becoming extremely foul and sources of much complaint.

The conditions have been somewhat improved by constructing considerable reservoirs, which, regulated by means of gates and used in connection with the tides, allow considerable currents to be maintained in most of the canals, and in this way the conditions have been maintained without becoming excessively bad. The limits of this system of flushing have, however, been nearly reached, and it is apparent that some further treatment will be required. Several of the leading Dutch engineers are exerting their ingenuity to see how a series of sewers can be constructed for The Hague, but the problems of ground water, canal crossings and pumping stations are really very serious.

In Amsterdam a portion of the central part of the city has been for some years sewered on the Liernur system. This system, which many of you will remember, was much talked about some years ago, and was thought by many to afford a solution of the sewerage problem. It consists of a system of iron pipes in which a partial vacuum is maintained, and into which sewage matters are passed without water, and the material is drawn in a concentrated form to a pumping station, where it is distilled with lime, giving off ammonia, which is condensed in acid to form an ammonium salt which is sold, and the residue is dried and compressed into cakes, which have some value as a fertilizer.

At the present time about 62,000 people are connected with this system in Amsterdam, and about six tons of ammonium sulphate are produced per week, which partially pays for the cost of operation. The system is being slowly extended to other parts of the city, although perhaps it is too soon to state that it is the definitely adopted plan of the city, and developments may be awaited. This is altogether the largest plant upon the Liernur system, and possesses very great interest to those only familiar with the water-carried system of sewerage.

The question as to the dilution which it is necessary to give a sewage or a sewage effluent in order to prevent the creation of a nuisance, is a most interesting one. Unfortunately, statistics as to the flow of streams at the points where they pass various cities are extremely difficult to obtain, and even in those cases where statements are available there is often a question as to the exact conditions under which the gaugings were obtained, and as to whether the results are comparable with corresponding statements for other places.

The flow of rivers, however, is in a measure proportional to the

areas of the watersheds from which they flow, and these watersheds can be measured with ease and with comparative accuracy. The flow, and particularly the minimum flow, in which we are especially interested, of course depends upon the rainfall, and its distribution throughout the different seasons of the year, as well as upon the climate and the geological character of the watershed. But after making due allowance for differences of this nature, the comparative figures for the areas of watersheds are more satisfactory than any records of gaugings which could be obtained for all the numerous points in which we are interested.

In the following table are given the names of a number of cities having interesting sewage disposal problems, and their populations, as given in the last census for 1890 or 1891, as the case may be, together with the rivers on which they are situated, and their drainage areas measured from the points at which sewage is discharged into them, and in the last column the areas of the drainage areas per thousand of population. The areas, with one or two exceptions, have been measured from maps and are only approximations.

City.	River.	Population.	Drainage Area.	Square Miles per 1,000 of Population.
Manchester	Irwell.	198,136	290	0.41
Salford		505,343		
Brussels	Senne.	477,000	340	0.72
Leeds	Aire.	367,506	310	0.84
Sheffield	Don.	324,243	320	0.99
Bradford	Aire.	216,361	220	1.02
Huddersfield		95,422	102	1.06
Chemnitz		138,955	160	1.15
London	Thames.	4,211,056	4,900	1.16
Glasgow	Clyde.	658,198	800	1.22
Berlin	Spree.	1,578,685	3,800	2.40
Munich	Isar.	348,000	1,200	3.45
Leipsic	Elster.	355,485	1,700	4.80
Brunswick	Ilse.	100,883	600	6.00
Paris	Seine.	2,447,957	16,000	6.50
Hanover	Leine.	163,100	2,000	12.30
Breslau	Oder.	335,174	8,500	25.50
Frankfort-on-Main	Main.	179,850	9,500	53.00

Manchester and Salford, on the opposite sides of the Irwell, discharge their sewage into it at nearly the same point, after treating it by chemical precipitation.

The population given for Brussels includes suburbs more populous in the aggregate than the city itself, and it is probable that only a part of them are connected with the sewers. The sewage is not treated and

the river is extremely foul below the city. The river has been straightened and arched over through the central part of the city, and a boulevard has been built over it, and intercepting sewers on either side of it are carried down to a point below the city, at which the sewage is discharged.

At Leeds the sewage is treated by chemical precipitation before being discharged into the Aire, and at Bradford also, the sewage is precipitated and discharged into a brook just above its junction with the Aire, but the drainage area given is that of the Aire below the junction of the brook.

Sheffield and Huddersfield treat their sewage by chemical precipitation and follow the treatment with rapid filtration.

The rivers mentioned above have been among the most grossly polluted rivers in Europe, and notwithstanding the efforts that have been made to purify the sewage, they are in far from satisfactory condition, although it seems probable that the large amount of cloudy weather, and absence of extremely hot weather in England in summer, at once have a tendency to maintain larger minimum flows, and are less favorable to the offensive decompositions that would be expected in a hotter climate and drier atmosphere.

Chemnitz discharges its sewage without treatment into the small stream which flows through it, and a serious nuisance is created which will probably be corrected in the near future. The stream has quite a rapid fall, and it is perhaps this fact which has made the discharge of so much sewage possible.

At London and Glasgow, the sewage is discharged into estuaries, where there are powerful tidal currents, in addition to the flows of fresh water, which render comparison of them with inland cities impossible. At London, the sewage is treated by chemical precipitation, and a similar treatment, followed by rapid filtration, has recently been put in operation to treat a portion of the sewage of Glasgow.

At Berlin, the condition of the Spree became very offensive in the early seventies, when the population was only half as great as at present, and the drainage area per thousand of population was consequently twice as great. Since that time, the sewage has been treated by broad irrigation, and the river is now in good condition.

At Munich, the sewage is discharged untreated into the river Isar, and has caused no serious nuisance. The river, however, has its origin in the Alps, and has a large flow and a rapid fall, so that the conditions for the discharge of crude sewage are unusually favorable.

At Leipsic, the untreated sewage has created a serious nuisance, and will be treated at an early date. Brunswick and Hanover do not treat their sewage, but probably will apply it to the land in the near future.

At Paris, the Seine has become extremely foul, notwithstanding its large drainage area and the fact that part of the sewage has been treated. Deepening the river to allow the passage of ships of considerable draft has reduced the velocity of the current, and made the conditions more favorable for the formation of deposits of sewage matter, with the decompositions which accompany them.

At Breslau, the sewage has been treated for many years by applying it to land, and the river has, so far as I know, never been in bad condition. Water taken from the river is used for public water supply by at least two large cities down the river.

At Frankfort-on-Main the sewage is treated by chemical precipitation before being discharged into the artificial harbor which has been constructed by building a dam at a little distance below, and by deepening the channel opposite the city.

While the data given in the table are perhaps hardly adequate to serve as a basis for final conclusions, they are interesting as showing the discharge of crude sewage without nuisance into a rapid mountain stream, having only 3.5 square miles of drainage area per thousand of population, while the discharge of sewage into smaller streams proportionally, has always resulted in the production of a nuisance, and other streams drawing their water from flat prairie country and with sluggish flows, have become offensively polluted, although their drainage areas were equal to 6 or 8 square miles per thousand of population, and one can readily see that in a region like the western part of the Mississippi basin, where rivers go nearly or entirely dry in summer, sewage might cause a nuisance even though the watershed was enormously greater proportionally than the above figures. We also see that cities have grown up upon rivers so small as to furnish less than half a mile of drainage area per thousand of population, and while in these cases, by giving the greatest attention to the thoroughness of the purification of the sewage before discharging it, rivers can be kept in fairly good condition, the problem is a difficult one and requires the utmost and continued care to keep the streams even in reasonably good condition.

In conclusion, the trend of the best European practice in sewage disposal is strongly toward the treatment or purification of sewage in all cases before it is discharged into rivers, with the exception of very large rivers, and at points where there are strong tidal currents. The tendency is to use land treatment wherever the local conditions are reasonably favorable, as the effluents produced in this way are of much greater purity than can be obtained by any chemical or mechanical processes, and the cost is ordinarily less. Where the local conditions are such as to preclude the employment of land treatment, chemical precipitation is

used, but although material improvements have been introduced in the construction of settling tanks and in the methods of applying chemicals, it is not possible to produce effluents of sufficient purity to be discharged into the smaller rivers without creating more or less complaint, and the tendency is strongly to follow chemical precipitation in such cases by a rapid filtration through some material which will remove substantially all of the remaining suspended matters, and will allow at least a portion of the soluble organic matters to become oxidized.

MECHANICAL ANALYSES OF SAMPLES OF MATERIALS FROM CERTAIN EUROPEAN AND AMERICAN SEWAGE FARMS.

COLLECTED BY THE AUTHOR.

(For methods of analyses see Report of Massachusetts State Board of Health for 1892, page 541.)

Location.	Description of Samples.	Effective Size, 10 per cent. finer than: (Millimeters).	Uniformity Coefficient.	Albuminoid Ammonia, Parts in 100,000 by weight.
Berlin, Malchow Farm.	Surface soil where it had recently been ploughed.	0.12	5.6	34.
" "	Subsoil two feet deep at same place.	0.12	3.4	33.
" "	Surface soil not recently ploughed.	0.12	2.2	90.
" "	Subsoil two feet deep at same place.	0.13	2.7	31.
Berlin, Grossbeeren Farm.	Surface soil in actual use.	0.15	2.0	26.
" "	From a sand bank near by representing the original unused material.	0.15	1.8	1.
Breslau.	Subsoil one foot below surface of sewage field in use.	0.24	1.9	2.
Paris.	Surface soil from sewage fields in use.	0.13	5.9	64.
Framingham, Mass.	Sand from sewage filters.	0.35 to 0.42	4. to 5.	
Marlborough, Mass.	" " "	0.12	3. to 4.	
Gardner, Mass.	" " "	0.10 to 0.24	6. to 14.	
Brockton, Mass.	" " "	0.30 to 0.60	2. to 5.	
Poughkeepsie, N. Y.	Sand from sewage filters at Vassar College.	0.10 to 0.50	2. to 5.	0. to 2.
Plainfield, N. J.	Sand from sewage filters.	0.10 to 0.25	2. to 5.	0 to 3.
Pullman, Ill.	Soil from sewage farm.	0.01	15.	225.

SOLID FLOOR BRIDGES FOR RAILROADS AND HIGHWAYS.

By Frank C. Osborn, Member of the Civil Engineers' Club of Cleveland.

[Read before the Club, November 12, 1895.*]

The term "Solid Floor," as applied to railroad bridges, is here used to distinguish the various types of continuous metal floors, as made up of plates and angles and other special shapes, from the ordinary open floor of timber cross-ties laid on longitudinal stringers or joists of wood or iron.

A highway bridge floor must necessarily be continuous and, in that sense, solid; but this paper refers to such types as might perhaps be better called "permanent" floors to distinguish the various forms of floors adapted to the use of brick, stone block, asphalt or macadam paving, as opposed to the more common floor of one or two thicknesses of plank laid on wood or iron joists.

The use of solid floors for railroad bridges has increased largely in the past few years, and has been brought about by various considerations, among which may be mentioned the following:—

(1) The elevation of tracks in the larger cities requires as shallow floors as possible, in order to give suitable clearance over streets, and this can best be accomplished by the use of all-metal floors. A closed floor is also necessary to prevent the falling into the street of coals, ashes, etc., from passing trains. It is also desirable as affording better protection in case of derailment.

(2) The solid floor is also used to give, as near as practicable, the same rigidity and permanency as the ballasted road-bed and a perfect support to trains, whether on or off the track.

The first solid-floor bridges for railway or highway purposes were doubtless those of masonry arches, and it would appear that, with the exception of a few of the earliest and crudest of the bridges of history, bridges with solid floors were the first used, and that the lighter, open and less expensive floors now so common, particularly in this country, are of more recent origin.

Following through the early history of bridge construction, masonry arches of various forms, cast-iron arches, etc., the first bridge built with a solid floor as we now understand the term, seems to have been the famous Britannia tubular bridge, built in 1845, Robert Stephenson,

* Manuscript received December 25, 1895.—*Secretary, Ass'n of Eng. Socs.*

engineer. The total length of this structure is 1511 feet, and the weight 9360 tons. It cost £601,865, or £64.3 per ton, equivalent to about 14 cents per pound. Drawings of this bridge are not easily attainable, but the sketch (Plate I, Fig. 1), gives a good idea of the arrangement of the floor. It consists of built stringers covered top and bottom by plates, the upper plates supporting the rails on wooden longitudinal sleepers and rail chairs. This solid floor was, however, incidental, as its first duty was to act as a bottom chord. The Britannia Bridge is still in service; a monument of the first bold departure from the then existing methods of bridge construction.

From that time to within the past twenty years it is difficult to find many specific examples to show the progress in solid metallic floors. There seems to have been but little interest taken in their design, and, though the English even at that time used solid floors almost exclusively, there seems to have been but little variety in the forms and devices used. Cast-iron decking plates of various forms were used for many years. Mr. Mallet's invention of buckled plates, somewhere about 1861, marks an interesting advance, and seems to be the first special form of wrought iron devised for flooring purposes. Prof. Rankine mentions this in his Civil Engineering.

The Severn Bridge, of the Severn & Wye and Severn Bridge Railway, was commenced in 1875 and opened in 1879. The following is a description of the floor: "The top and bottom chords of the span are connected by vertical members which carry the cross girders. Small longitudinal girders between the cross girders support the rails, and the floor is made of plate iron decking."

The New Tay Bridge was built between 1881 and 1887, to replace the older bridge, which had failed in December, 1879. The plans for this bridge were approved in 1881, and included a trough floor of the form shown (Plate I, Fig. 2). Cross girders were used over the piers, but elsewhere they were dispensed with. The floor troughs rest on the bottom flanges of the girders and are riveted by means of angles to a continuous web forming part of the bottom chord. The troughs are filled with ash and cinder ballast, and the cross-ties are laid therein, spaced rather closely together.

This appears to have been the first form of trough floor designed, and following it a large number of different forms were devised, some of them patented, and used on various bridges. Conspicuous among these is Lindsey's floor (Plate I, Fig. 3), a form which has found great favor both in Europe and America, and one still frequently used. The drawing shows a floor for a short plate girder bridge, using the "C Max." troughs laid transversely and intended to be used with rail resting on a longitudinal sleeper bolted to the tops of the troughs. This section has

a moment of resistance of 198.9 inch tons, and weighs 32.97 pounds per square foot of floor. The largest form rolled is shown in the small sketch. This form has a moment of resistance of 1325.15 inch tons, and weighs 56.76 pounds per square foot.

In 1887 Mr. Edmund Olander read an exceedingly interesting paper before the Society of Engineers, entitled "Bridge Floors, Their Design, Strength and Cost." In this paper Mr. Olander discussed all the principal forms that had appeared up to that time, reducing them to a common depth and weight per square foot of actual area covered, and determining their comparative strengths and costs. Some of the more interesting forms are shown on Plate I, Fig. 5. Of these, No. 1 was an ideal section introduced by Mr. Olander for comparison. No. 4 is a form made by Messrs. Braithwaite & Kirk, patentees, West Bromwitch, and used, some two years ago, by Mr. Copperthwaite, M. I. C. E., on the southern section of the North Eastern Railway, for a bridge of 64 feet span. A form similar to No. 4 was used on the Tower Bridge, London, the principal difference from the form illustrated being the elimination of the joint and line of rivets at the bottom of trough, making a complete trough of each piece and jointed with one line of rivets at the upper part only. No. 5 is Baillie's patent floor. No. 6 will be recognized as the general shape of trough floor so much in use in America during the past five or six years, and it is interesting to note that for the dimensions used by Mr. Olander for comparison with the other forms, he finds this to rank lowest in his list of ten sections discussed, it having the largest number of rivets and the lowest moment of resistance. One other form discussed by Mr. Olander is the Lindsey floor, described above; the others of the ten are uninteresting in comparison with these, and have been but little used.

Later, Hobson's Patent Floor appeared (Plate I, Fig. 6), composed of several forms of bent plates connected by tees and made water-tight by a filling of asphalt in the V-shaped channels. The sketch shows the floor as adopted for the Liverpool Overhead Railway, six miles in length, and built within the past three or four years. Messrs. Greathead and Fox, in a paper before the Inst. C. E. (Vol. CXVII, pp. 51–70), gives the following description of the flooring:

"Between the girders (the main girders of the viaduct), is fixed Hobson arched-plate flooring, consisting of $\frac{5}{16}$-inch plates, bent to a radius of 12 inches, with a flat surface 6 inches wide on the top, riveted to intervening tee bars, and made water-tight by asphalt placed in the vee-channels between the arches. Upon this are laid longitudinal creosoted sleepers keyed to the flooring, and no ballast is used. From each vee-channel an outlet for water is provided through the web of one of the main girders, discharging into a light cast-iron gutter carried

along the outside of the main girder, which conveys the water to a rectangular down pipe fixed to the columns and delivering into the drains or gutters below. This flooring combines great strength with lightness and minimum of riveting, while the load is more evenly distributed along the main girders than is the case where cross girders are employed, and great lateral stiffness is secured without horizontal bracing. The flooring is practically water-tight, and after twelve months' test under traffic has not shown any defects. In order to ascertain the strength of the floor, some sections were tested to destruction, and the deflections at each increase of load carefully tabulated with the following results:

"TEST:—Three sections of floor measuring 7 feet 6 inches in width; span 22 feet, ends resting upon supports; load distributed over four points corresponding with the positions of the rails.

Load, Tons.	Deflection at Center.
30	Nil
35	$\frac{1}{4}$ inch
40	$\frac{7}{16}$ "
50	$\frac{9}{16}$ "
60	$\frac{3}{4}$ "
70	$\frac{15}{16}$ "
80	$1\frac{1}{8}$ "
90	$1\frac{1}{4}$ "
100	$1\frac{9}{16}$ "
110	2 inches

"The floor-plates ultimately collapsed by a total rupture of the tee-bars at 163 tons, and with a deflection of 10 inches.

"In the preliminary stages of manufacture of the floor considerable difficulty was experienced. The plates were heated in a furnace and were bent in a hydraulic press by dies to the required form, but it was found that in cooling the extreme ends curled upwards and spread outwards. After many trials, and by giving the dies a "set" in opposite directions, and by fixing the plates in a simply constructed frame to cool, truth and uniformity in the shape of the plates was eventually secured. The rivet holes along both edges of the plates were then drilled simultaneously by special machinery. The system was brought to such perfection, that from a single heating oven and press, and from one drilling machine, occasionally 45 plates, or sufficient to floor the viaduct for a length of 112 feet, were turned out daily, bent, drilled and ready for fixing. At the final operation, 344 plates were pressed in six days by one gang of men. When they were ready, bent and drilled, a tee-bar was riveted between them at their springing. The rivets were closed up by means of machine riveters, both heads being easily accessible from the under side. The rivets were put in by each machine at the rate of 400 per hour."

The following description of the solid floor on the Forth Bridge, begun 1882, completed 1890, is taken from *Engineering News:*

"The bridge carries a double track railway, and each line of rails is laid in a trough built up of plates and angles forming a guard on each side of each rail (Plate I, Fig. 8). The tracks were laid with rails of bridge section, weighing 120 pounds per yard, and about 28 feet long. They are secured to teak longitudinals by screw spikes 8 inches long, which pass through the flanges of the rail. The longitudinals are about 12 inches by 6 inches in section, and are kept in line by horizontal wedges driven between them and the sides of the troughs, which prevent the use of transverse connections. At joints and some other places a filling of vertical creosoted pine blocks is used, making a good-looking piece of work, and being very safe in case of derailment. It is not to be put in continuously, however, partly on account of the cost, and partly as it would prevent inspection of parts of the iron work of the trough. The timbers rest upon a continuous bearing of wooden blocks with pitch filling. The floor is of buckle plates with holes to let off the water. There is no ballast. The floor seems to be very rigid and without sufficient provision for cushioning the vibrations started by trains. The trains make a harsh metallic sound and a jarring in passing over the bridge, and this noise and uneasy jarring are unpleasantly noticeable in riding in the cars. The change is very pronounced when the train runs into the embankment approach, where the track is laid with the same rails on longitudinals, with transoms, in broken stone ballast; the train then riding smoothly and quietly."

All, or nearly all, of the English railways use solid floors extensively on their bridges. The Great Western Railway uses troughs laid transversely and filled with ballast. Trough floors are also used on the Great Eastern Railway, notably on that part not far from the Liverpool Street terminus where the track is elevated on brick viaducts with plate girder bridges across the streets.

The great bridge over the Mersey at Runcorn has an iron floor, with angle iron guard rails on each side of and at some distance from the track rails, forming a wide trough.

When, between 1886 and 1890, the London & Southwestern Railway widened its line to accommodate two more lines of track, and replaced its oldest cast-iron bridges with girders, a trough floor was used on the bridges of the form described in connection with the Tower Bridge, London, resting on the bottom flanges of the girders. The troughs were made eight inches deep, of ½-inch metal, which received two coats of Stockholm tar after they were placed in position, and then filled with a mixture of tar and gravel.

The rails are supported on longitudinal timbers, 18 inches by 7

inches, secured to the floor troughs by angles. To carry off the surface drainage, there is a 1-inch hole in each trough, close to the connection with the central girder, this girder being set $1\frac{1}{2}$ inches low, and a wrought-iron girder is riveted to the soffit of the flooring, and carried to the abutments, whence the water is conveyed to the street sewer by a down pipe built in a chase.

These works are very completely described, and results of tests of the flooring given in a paper by Mr. Alfred Weeks Szlumper, before the Inst. C. E. (see Vol. CVII, pp. 287–304).

The writer has lately had called to his attention a new English floor known as Knight's Improved Steel Floor Plate. This form was patented October 16, 1894, and is intended for use on all kinds of bridges as well as for warehouse floors, etc. The drawing (Plate I, Fig. 7) shows its method of application longitudinally for a railroad girder bridge, but it can be placed in any position, with troughs running longitudinally or transversely, and either side up. The inventor claims the combined advantages of both trough and buckle plate forms.

The Swiss Northeastern Railway has in use several bridges with solid trough floors. The type is shown by the drawing (Plate 1, Fig. 4). The troughs are used both transversely and longitudinally, the form of trough being decidedly different from others. One distinguishing feature of these bridges is the method of carrying the ballast uninterruptedly from bank to bank. This mode of construction is found to make the structures from 10 per cent. to 15 per cent. heavier and more expensive, but on the other hand their vibrations are reduced almost to a minimum. The troughs rest on flat straps of iron $\frac{25}{32}$ inch high and about 2 inches wide, fastened to the tops of the floor beams by countersunk rivets. These straps serve to protect the angles of the floor beams from being bent downward from strains on the troughs, and also to transmit the live loads to the floor beams axially. On both sides of the track, sheets of iron are placed, resting against the gusset plates connecting the floor beams with the main girders. The box thus formed receives the ballasting to the height of 12 inches above the tops of the troughs. The ballast rests upon a solid layer of concrete, which covers the troughs entirely. A very strong and heavy cross-section of trough is used, the width of foot being 12 inches, height 5 inches, weight per yard 62.5 pounds, material, mild steel.

A peculiar solid floor on a single track railway bridge in Germany is described in the *Centralblatt der Bauerwaltung* by Reinhard Goering. The transverse girders are connected by five stringers which are covered by trough plates filled with concrete. The concrete is covered in turn by asphalt, forming a firm bed for a course of corrugated galvanized iron. The corrugations are 6 inches wide and 18 inches

deep, running across the bridge. On this is gravel ballast confined at the sides by metal plates, forming an inclined curb. The drainage water percolates through the gravel to the corrugated iron, and thence by longitudinal sheet-zinc troughs to the earth back of the abutments. The total cost of the floor is said to be 95 cents per square foot.

Solid floors are used extensively in India, many forms being in use. Some of the older brick arches were repaired by making a solid floor of old rails laid lengthwise and covered by at least 9 inches of ballast. Some buckle-plate and trough-shapes are used, and Messrs. Dorman, Long & Co., Limited, of Middlesborough, England, illustrate a special shape of troughing in their hand-book of steel sections for use on the Indian State Railways. It is very like the form used on the Tower Bridge in London, and described above.

In America, solid floors for railroad bridges were not introduced extensively until within a comparatively recent period. It is true, a few bridges were built with floors which would be properly considered in this history, although not included precisely within the term as generally used in connection with railroad bridges, since they were used not so much for the reasons now so seriously considered as to obtain a bridge floor safe against fire, or, on short spans, to cheapen the cost of the floor by omitting the common form of floor-beams and stringers.

As early as 1874, small bridges were built with a floor of old rails laid crosswise directly upon the top chords of the girders or trusses, and covered with ballast in which were bedded the ties. Several such bridges still exist and give satisfaction. A number of rail floors were laid on the New York Central about 1874 and later, consisting of old rails laid lengthwise, directly upon the abutments of short spans, and close together for 12 feet in width. Upon these were placed one foot of gravel ballast and the track laid directly thereon.

There is a peculiar metal floor on the N. Y. & N. E. R. R. bridge over the N. Y. C. & H. R. R. R. tracks, at Fishkill, N. Y., which, while it cannot be properly classed as a solid floor, is interesting in connection with rail floors. It consists of built floor-beams and stringers of usual construction, but instead of using wooden ties, old rails, planed on the ball, are placed across the stringers upside down, and held in position by bent plates riveted to the top flanges of the stringers and bolted to the webs of the rails. Upon these the track and guard rails (the latter also of railroad rails) are laid and fastened, and lines of $\frac{5}{16}$-inch deck plates are laid between the track and guard rails and for a width of 14 inches inside of the track rails on each side.

For a number of years, also, wooden trestles have been in use on some of our railroads, with solid wooden floors covered with ballast.

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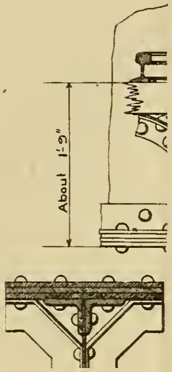


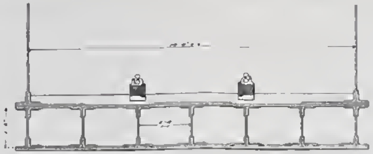


Fig. 1.
Britannia Bridge.

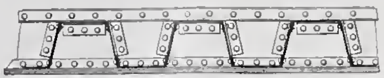
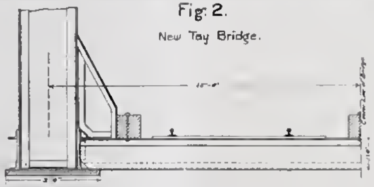


Fig. 2.
New Tay Bridge.



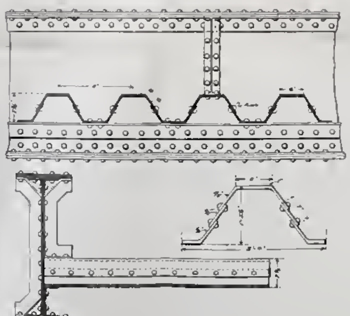


Fig. 3.
Lindsey's Floor.

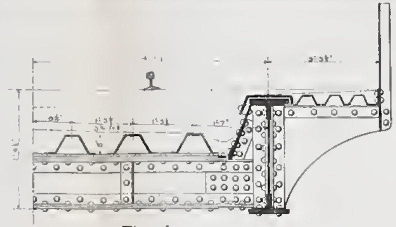


Fig. 4.
Swiss Northeastern Ry.

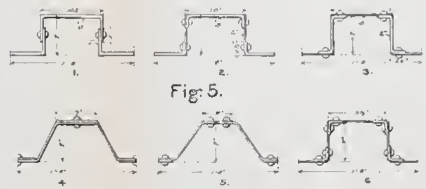


Fig. 5.

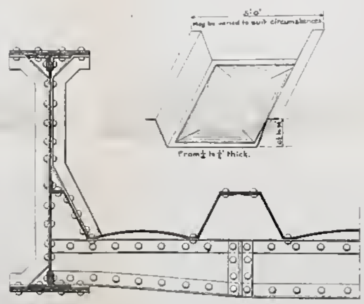


Fig. 7.
Knights Patent Floor.

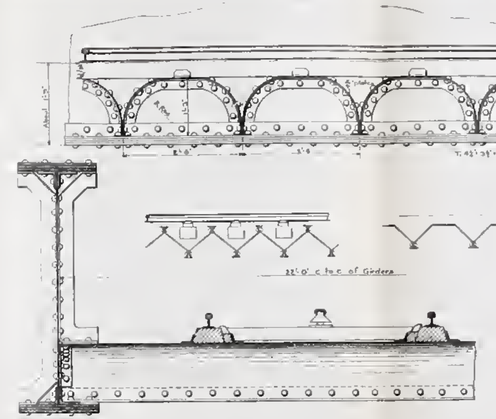


Fig. 6.
Hobson's Flooring.

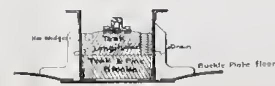


Fig. 8.
Forth Bridge.

Solid Floor Bridges for Highways & Railroads.
PLATE I.
European Bridge Floors.

to accompany paper by Frank C. Osborn

For illustration, the type of wooden trestle used in many places on the Southern Pacific Railway is shown on Plate III, Fig. 7. This type of floor has been used on this road since 1887. Mr. Julius Kruttschnitt, to whom the writer is indebted for plan and description of the floor, says:

"These ballasted structures are built of creosoted timber only, which we treat at our own wood-preserving works near Houston. Their cost, for heights varying from 4 to 12 feet, is from $8.00 to $8.50 per lineal foot, built under traffic, the lower cost applying to trestles of four or more panels, and the higher to trestles of less than four panels.

"We have never experienced the least want of better drainage, or any lack of stiffness, as you can well imagine from the substantial character of the floor.

"Perhaps the best manner in which to illustrate our faith in this style of floor, would be to state that on January 1, 1895, we had some 45,730 lineal feet of these structures in our main line of 1200 miles, and from the time of their inception to the present time, we have spent nothing on them for ordinary repairs.

"The durability of these structures depends, in the main, upon the life of the creosoted timber used in their construction, and whilst this life is not within the range of our own experience, we are led to believe from the experience of others that we can conservatively count on twenty years, at least."

Several other railroads have wooden trestles with solid ballasted floors. The Houston and Texas Central Railroad has a standard type of trestle differing somewhat from that of the Southern Pacific. Eight lines of 7 x 14 inch stringers are placed on the caps of the bents, and are covered with 2 x 12 inch planking 14 feet long, laid crosswise. 4 x 6 inch longitudinal pieces are bolted to the ends of the planking to catch the ballast. The track is laid in the ballast in the ordinary manner. This type is also built of creosoted timber, and the average cost is $8.50 per lineal foot.

The Illinois Central Railroad has also used solid floor trestles on some of its southern divisions, built of black and red cypress without creosoting. Their life is estimated at twelve years. The general design of the floor is very much like that of the Southern Pacific type.

Mr. Wolcott C. Foster, in his book on "Wooden Trestle Bridges," illustrates a solid floor pile trestle, with ballasted road-bed, used on the Louisville and Nashville Railroad. The Richmond, Fredericksburg and Potomac Railroad also uses a ballasted wooden floor on trestles as a protection against fire and to deaden the noise. Mr. E. T. D. Myers, in writing of this floor, says: "Our experience goes to show that the supporting wooden stringers are quite as durable, if not more so, under such treatment."

A noticeable point in all these wooden floors is the absence of guard rail of any kind, the track being laid and maintained in the ballast precisely the same as upon other parts of the road.

Some time in 1887, Mr. George S. Morison prepared plans for his bridge across the Willamette River. The conditions surrounding its construction were such that a very stiff and permanent floor must be designed with very scant depth. Mr. Morison went across the water for his idea, and adopted the Lindsey trough for the floor of this bridge, using a section about 12 inches deep. This, so far as the writer is able to determine, is the first instance of a solid metal trough floor used in America. Later, in designing a bridge in Omaha, Mr. Morison had occasion to use a solid floor in order that the tracks might be laid upon it in any position and that a tight floor over the street might be obtained. He prepared patterns for a trough shape similar to that used upon his Willamette bridge, and the troughs were rolled by the Pencoyd Iron Works. This appears to have been the origin of the "Pencoyd Section" still so frequently used, and to account for the similarity between this section and the earlier design of Lindsey's floor in England.

Shortly after this, or in 1888, the New York Central began its work of building solid trough floors for bridges and covering them with ballast, thus obtaining a continuous ballasted track from bank to bank. This road is conceded to have been the first to adopt solid metal floors as a standard, and appears to have adopted this standard in compliance with a law enacted in the State of New York, on November 1, 1887, providing that floor systems shall be maintained on all bridges so constructed as to support a derailed locomotive or cars. The first of these to be built was bridge No. 547 on the Mohawk and Hudson Division, and the form of ballasted trough adopted for that case is essentially the same that has been most extensively used ever since on this road, consisting of plates and angles forming parallel square troughs, in which are placed the ties on ballast.

The drawings (Plate II, Figs. 1 and 2) show two types of floors used on their shorter spans. The first is Pencoyd's Section No. 209, weighing 24.8 pounds per square foot. This is said to be the cheaper form for small openings. The other form is their standard square trough. The drawing shows the floor on the four-track bridge over the 165th Street sewer. The total length is 24 feet, clear span 21 feet, and 2 feet depth of floor. The cost, including ballast, etc., was $500 per track, equivalent to about $21 per lineal foot of single track.

The Oriskany Bridge, on this road, was built in 1889 and carries a solid floor of the square trough pattern suspended by angle hangers from a stiff bottom chord. This, like most of the others, is ballasted. The floors of the longer spans are built with the troughs running transversely

instead of longitudinally, as shown on the drawings representing the shorter spans.

The New York Central is now finishing a large bridge and viaduct approach over the Harlem River, using the same square troughs, but in this case they expect to rest the rails directly upon the troughs, fastening them on rail-plates by means of a special clip. On the approach, also, the design has been slightly changed in detail to facilitate field riveting by increasing the width of the top horizontal plate at the field splices of the floor and turning the corresponding angle into the trough. This does away with so much field riveting through the floor.

In the summer of 1889, Mr. A. F. Robinson, then in the employ of Mr. E. L. Corthell, designed the solid floors for the Clyde crossing of the Chicago, Madison & Northern Railroad over the tracks of the Chicago, Burlington & Quincy Railroad, near Chicago. This was also a square trough, 12 inches deep, resting upon shelf angles riveted to the stiff bottom chord of the pin-connected truss, or to the web of the girders, just above the flange. By this design a total depth from base of rail to bottom of structure of only 18 inches was obtained. Shelf angles were riveted at intervals in the troughs 6 inches below the tops, and the 8-inch ties rested upon these angles, thus clearing the rail 2 inches above the iron work.

The New York, Providence & Boston Railroad began giving attention to metalic solid floors about 1889. Their bridge No. 69 at Saundersville, Mass., was built during the summer of that year. It consists of Pencoyd Section No. 209, 57.9 pounds per yard, filled with asphalt and ballast. Several other cases might be noted where one or the other of these two forms of trough, viz., the square trough of plates and angles and the Pencoyd Section, were used previous to 1890, but up to that date there seems to have been no other form applied.

But, that American engineers were rapidly waking up to the great advantage and many merits of solid metal floors for railroad bridges, is evident from the greatly increased space given to their consideration in the engineering papers from this time on, and by the following extract from President Wm. P. Shinn's annual address before the convention of the American Society of Civil Engineers in 1890:

"The subject of bridge floors is one which has long needed more careful attention, and it is gratifying to observe that the New York Central has awakened to its importance, and is now building or refitting many of the short-span bridges with solid buckle plate or plate-iron floors, upon which the ballast is carried uninterruptedly. Every experienced engineer of maintenance of way knows how extremely difficult it is to secure and maintain such perfection of surface that the transitions from ballast to track on wooden bridge floors and vice versa shall be

smooth and without shock. This difficulty is avoided by the character of floor adopted by the New York Central. Its advantage in case of derailment was shown on November 12, 1889, when five cars of the west-bound freight train left the rails and dragged across the new Erie Canal Bridge at Rome, which had been provided with a floor of this character. The cars were scattered all over, two having their trucks pulled from under them; the ties and road-bed were torn up so that it looked as if the company had been trying to run one train on two tracks, but no damage was done to the bridge. It is plain that true economy calls for construction of this character, where it is possible, or where, as is being done by the Pennsylvania Railroad Company, it is not found practicable to replace the iron bridges with stone arches."

From this time forward, other forms rapidly came into use, and new designs or modifications of older ones appeared in rapid succession as the details of construction for various needs and special cases were worked out by different minds.

Mr. Robinson read a paper before the American Society of Civil Engineers in September, 1892, presenting a design for a solid trough floor. His object was to obtain a shallow floor of the most acceptable pattern, and he adopted a square trough of plates and angles, differing only in detail from that which he used in the design of the Clyde Viaduct, already described. He uses a pin-connected span without the stiff bottom chord and connects his troughs by bent plate hangers to an auxiliary plate girder which is fastened to the posts below the lower chord pins. He uses wooden ties resting on bent plate shelf supports in the troughs. Mr. Robinson gives the following reasons for adopting the square trough of plates and angles:—

"*First.* For through bridges the box floor must be suspended (on account of scant head-room), which makes vertical webs necessary.

"*Second.* A floor is required in which the width and depth of the boxes can be easily varied.

"*Third.* In section No. 4 (see No. 2 of Fig. 5, Plate I), there are channel bars, the price of which is usually controlled by a pool. In section No. 5 (see No. 3 of Fig. 5, Plate I), there are Z-bars which are not, at present, rolled as deep as necessary for our floor."

Mr. Geo. H. Thomson, in discussing the above paper, presented drawings of several forms of metal floors used by him in various bridges. One of them is of interest here, being different from those thus far discussed. It consists of Pencoyd Section No. 260, connected by horizontal plates, the troughs thus formed are riveted to the top flanges of the main girders and the bottoms filled with asphalt concrete laid to drain to the center, the concrete covered with stone ballast six inches deep between tops of troughs and bottoms of the wooden ties. Mr. Thomson says of this form :—

"Some difficulty is experienced in making the troughs fit the girders, owing to the stretch of the former after manufacture."

The discussion of Mr. Robinson's paper also brought out the suggestion of a new form of trough which, though it has never been used, is worthy of mention. Mr. Barbour wrote to the *Engineering Record*, under date of September 29, 1892, suggesting a floor of channels and plates (Plate II, Fig. 10), claiming economy in such a form. In a later communication Mr. W. Bleddyn Powell says:—

"I would respectfully urge in place of such a section one composed of Z-bars, as the distribution of metal in the entire section would then be equal, whereas with the section proposed the spaces back of the channels would require for the bottom plates a section 50 per cent. or 75 per cent. greater than those forming the top chord over the flanges of the channels. The necessity of built-up sections for use in bridge floors, other than those contained in the mill books, does not seem to me to be of special interest or importance."

In a still later letter Mr. Barbour defends his channel section, stating that it can be used to greater depths than Z-bars.

About this time (1892), there was built the plate girder bridge carrying the New York, Providence & Boston Railroad into the station at Worcester, Mass., including a floor very different from anything that had yet been devised. This floor, shown on Plate II, Fig. 3, was designed and patented by Mr. J. R. Worcester, Chief Engineer of the Boston Bridge Works. It consists of a series of parallel V-shaped troughs of plates and angles running transversely and connected to the webs of the girders by angles and brackets. Along the center line of the bridge, the floor is stiffened by V-shaped plates fitting into the troughs and secured by angles, as shown in the small sketch accompanying the drawing. The troughs are filled with concrete to a height of 5 inches above their tops, upon which is laid the ballast and track in the usual manner.

All the bridges of the Adirondack & St. Lawrence Railroad have solid floors, those under 10 feet span having rail floors, from 10 feet to 34 feet having longitudinal troughs, and over 34 feet span transverse troughs. The Trenton Falls bridge on this road is a three-span structure, completed during the winter of 1892–93, the central span being 100 feet in length and fitted with the square form of trough already described. The other two spans are shorter and have a different type of floor trough, shown on Plate II, Fig. 5. It consists of a trough similar to the other but shallower and built without the vertical plates, the vertical legs of the angles being long enough to be riveted directly together.

Few of the floors up to this time had been especially designed to be

water-tight so as to be suitable for overhead street crossings. In some cases this had been effected, but the conditions had not been many where such were required. But as soon as solid floors began to be contemplated in connection with designs for the abolition of grade crossings in cities, the problem of water-tight bridge floors provided with proper drainage naturally arose and became an important one.

Among the first to build a system of overhead bridges was the Illinois Central Railroad, when, during 1892 and 1893, that road carried out its great task of elevating its main tracks within the city limits of Chicago. The form of floor adopted for these bridges was the Pencoyd Section, chiefly because that was the only suitable ready rolled shape, and limited time prevented the consideration of other more complicated forms. These trough floors are 6 inches deep and all rest on shelf angles riveted to the webs of the girders. The successive changes in the method of laying the track on these floors and the reasons determining these changes are very interesting.

The original plan for bridges not over 13 feet wide, center to center of girders, contemplated putting asphalt in the troughs and placing the ties upon this. But the heavy traffic during the World's Fair prevented this from being accomplished either at first or afterward, so that for over a year the tracks were operated with the ties resting directly on the lower part of the troughs without any cushion, just as they were temporarily placed at first. During this time the accumulation of sand, gravel ballast, cinders, etc., around and under the ties was assisting immensely in the rusting process, and during 1894 the tracks were raised and the ties placed on the *upper* part of the troughs. This is the present state of these floors, leaving the metal free to be cleaned and painted when necessary, and always exposed so that no rust can escape discovery.

A different method of laying the track on bridges wider than 13 feet, center to center, consists of fastening the rail to longitudinal stringers by Marshall clips, the stringers being about 4 inches high and placed between two 8-inch deck beams riveted to the floor, thus forming an inner and outer guard rail. This design is so worked out that the rail is insulated on wooden bearings, etc., so that an electric signalling apparatus will work automatically with a track circuit.

Still another way that the Illinois Central is using this same trough, though of deeper section, is to cover it with ballast to a depth of 2 inches over the upper parts and lay the ties and rails thereon without guard rail.

These floors are all provided with drainage holes through the troughs at each end, near the girder connection; and the original plan included the placing of gutters under the girders leading to down spouts near the column supports where the floors were used over streets.

The Gaspee and Promenade streets bridges of the Boston and Providence Railroad, near the Providence station, were completed in the fall of 1894. The shape of the floor used is shown on Plate II, Fig. 4, and was a complete departure from any existing patterns. The conditions surrounding the construction of these bridges required a possible change in the location of the tracks after completion, and this condition, together with the large area of the bridge, made it impossible to so treat the structure as to shed water at the ends or sides. To support the assumed loads a series of troughs 10 inches deep was required. The deepest available rolled troughs with tight bottom at that time being only 6 inches, and even this, having awkward features in shop construction, led to the design adopted. The inventors and patentees of this floor are Messrs. George B. Francis and E. P. Dawley. The particular merits claimed for their floor are: (1) Simplicity in rolling; (2) adaptability to power riveting; (3) elimination of difficulty in accurate spacing, center to center of shapes; (4) smooth base on which to rest; (5) avoidance of rivet holes in bottom or tension flange when treated as a girder; (6) water-tight bottom, and (7) a variability in height within reasonable limits while preserving all of the other features. The shapes are so placed that the water collected in the troughs is discharged at the ends, where they rest on shelf angles on the webs of the intermediate longitudinal box girders, and flows into gutters and down spouts placed for the purpose.

The Chicago and Northwestern Railway adopted a floor differing again from existing styles. It was designed by Mr. Louis H. Evans and consists, as shown on Plate II, Fig. 7, of floor beams built of a vertical plate and two channels 10 inches deep, with heavy top and bottom plate forming an I-section and connected to the main girders by the ordinary gusset plates. Upon these beams is laid plate-decking $\frac{5}{16}$ inch thick. The rails are carried on wooden blocks laid in trough stringers built of a plate and angles, the angles forming a built Z-bar. It was originally intended to use Z-bars in this place, but the plan was afterward changed to the one shown. The troughs are not water-tight, having no bottom plate except at the ends, where a short plate is riveted through the bearing plate to the shelf angle to furnish end bearing for the rail blocks. These blocks raise the rails to clear the top plates of the beams, but no provision appears to have been made to hold them firmly in place. Outside the trough a continuous angle is riveted to the plate-decking to serve as a guard-rail.

The Denver & Rio Grande Railroad has lately gotten out a standard shallow floor for girders that is in principle somewhat like that of the Northwestern floor. The floor, designed by Mr. J. C. Bland, is shown on Plate II, Fig. 6. It is designed for the heaviest engine concentra-

tions, and the details have been worked out with care. In this floor also, there are floor beams of plates and channels,but in this case they are placed backs outward with two cover plates over the top and angles riveted to the lower part of the webs to support the troughs. The entire width of the bridge is covered by these longitudinal troughs built of Z-bars 5 inches deep, connected by horizontal plates above and below. The bottom plates of the troughs stop short of the connection angles and within the trough at this point a short angle is riveted to the lower flange of the Zs, thus leaving a slot $\frac{1}{2}$ inch by $3\frac{1}{2}$ inches, through which the drainage water escapes. The troughs are filled with bituminous concrete nearly level with the tops of the ties, or even with the tops of the short check angles mentioned above. The ties rest directly upon the troughs and are not dapped down upon them, but the guard rail, instead of being dapped over the ties in the usual manner, is let down upon them by dapping ties and guard rail each one inch. Ties and guard rail are then bolted down upon the troughs.

The Lake Shore & Michigan Southern and the Chicago, Rock Island & Pacific Railways have been doing considerable work during the past two years, requiring the use of water-tight solid floors, in the elevation of their tracks within the city of Chicago. At first the form of floor used was practically the same as that so generally in use on the New York Central: viz., square troughs built of plates and angles. The depth of this floor is $10\frac{1}{2}$ inches and the troughs are spaced $21\frac{1}{2}$ inches center to center. The flooring fits between the lower chord flanges of the girders with a clearance of one inch on each side for drainage, and its under side is on a level with the bottom of the girder flange. The floor is reinforced at the ends and provided with plates and angles which rest on the vertical legs of the girder flange angles and rivets to the web of the girders. It is also stiffened against the girders with gusset plates and angles riveted to the tops of the corrugations and the vertical web stiffeners. Upon the floor, and riveted to it through the reinforced angles on each side of every corrugation, are rail plates under each rail, and the rails are fastened directly to those plates by special clips. Gutters to catch the drainage water are placed under each girder, leading to down spouts at the column supports emptying into the street gutters.

But during the past year the design has been entirely changed and all the bridges built within the past year have been supplied with a very different floor. It consists (see Plate II, Fig. 8), of 10-inch by 33-pound I-beams cut at the ends to an angle of about 60 degrees, with $9\frac{1}{4}$-inch by $\frac{7}{16}$-inch hanger plates riveted to each end in the shop by means of angle lugs riveted to the webs. These floor beams are riveted to the girders in the field with five rivets connecting each hanger to the web, and with two rivets to one of the bottom cover plates of the main girder,

made wider for this purpose, for side stiffness. A continuous sheet of $\frac{5}{16}$-inch steel plates is placed upon the floor beams and riveted to them. It is riveted to the sides of the girders with a continuous seam through the angle irons, provided and spliced at the joints with 5-inch by $\frac{3}{8}$-inch lap plates placed below the surface. The girders are cambered $\frac{3}{8}$ inches and the drainage is from the center to the ends of the bridge, and at each end the sheet covering is finished with an angle iron, and provided with a gutter of $\frac{1}{8}$-inch sheet steel, which drains into a groove cut into the coping of the masonry and from there into the earth fill behind the abutments.

Upon the plate covering of the floor, and riveted to it and the floor beams, are laid the rail plates and angle guard rail. The rail plates are alternately arranged for rail fastenings and for rail bearings only. The rails are fastened to these rail plates by means of special close-fitting clips bolted snugly to place.

Both the foregoing plans were designed by Mr. Albert Lucius, Consulting Engineer.

Of late the New York Central has also adopted a similar floor as a standard for through girder bridges. In their plan, however, the beams are connected directly to the webs of the girders by heavy angles and they are covered with plates only between the guard rails, which are made of angles laid each side of each rail, flaring out at the ends of the bridge. The rails are held in place by a similar clip and are separated from the metal work by indurated fibre, thus insulating them for electric signalling purposes.

The writer has lately had occasion to design a solid floor for a system of elevated tracks over street crossings, which is illustrated by Fig. 9, Plate II. This floor consists of transverse beams of I-section built up of 3-inch by 3-inch angles and 12-inch web plates, and extending the full width of the bridge. These beams are connected to the girders by means of 6-inch by 6-inch angles which rivet to the web plates of the beams and directly to the main girders without the aid of gusset plates. On top of the beams continuous floor plates are riveted, making an unbroken water-tight deck. The rails are attached directly to the iron work, resting on bearing plates about $\frac{1}{2}$ inch thick and, when necessary for insulating purposes, indurated fibre plates may be placed between the rails and the $\frac{1}{2}$-inch bearing plates. The floor plates with their splices are placed lengthwise of the bridge, so that, with the assistance of the camber or the grade or both, the water may drain to the ends of the bridge and there be taken care of by properly arranged drains. It will be noted that this floor is made up of the most readily obtainable material, plates and angles, and the workmanship is of the simplest character.

A review of the history of the design of solid metal railroad bridge

floors reveals a curious fact. The earliest design on record is composed of built beams supporting an iron decking, and the latest forms introduced are quite similar; a remarkable illustration of the old saying that "history repeats itself."

It seems proper here to call attention to the fact that a number of our larger railway systems, principally those in the East, are obtaining solid floors in a great many cases by replacing their shorter iron spans by masonry arches, which enables them to carry their road-bed uninterruptedly from bank to bank.

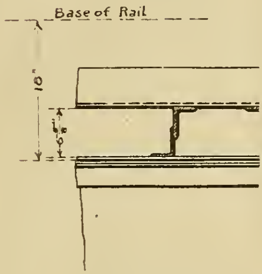
In designing a solid floor, consideration should be given to the following features: Accessibility for examination and painting; facilities for thorough and rapid draining; use of shapes and sizes readily obtainable from the mills; simplicity of shop construction; cheapness of first cost and cost of maintenance; convenience of changing location of track to accommodate switches, frogs, etc.; and the attachment of floor to girders should be effective, simple, and as direct as practicable. Eccentricity of connections should be avoided. The floor should be arranged to carry a derailed train with as little damage to it or the bridge as possible.

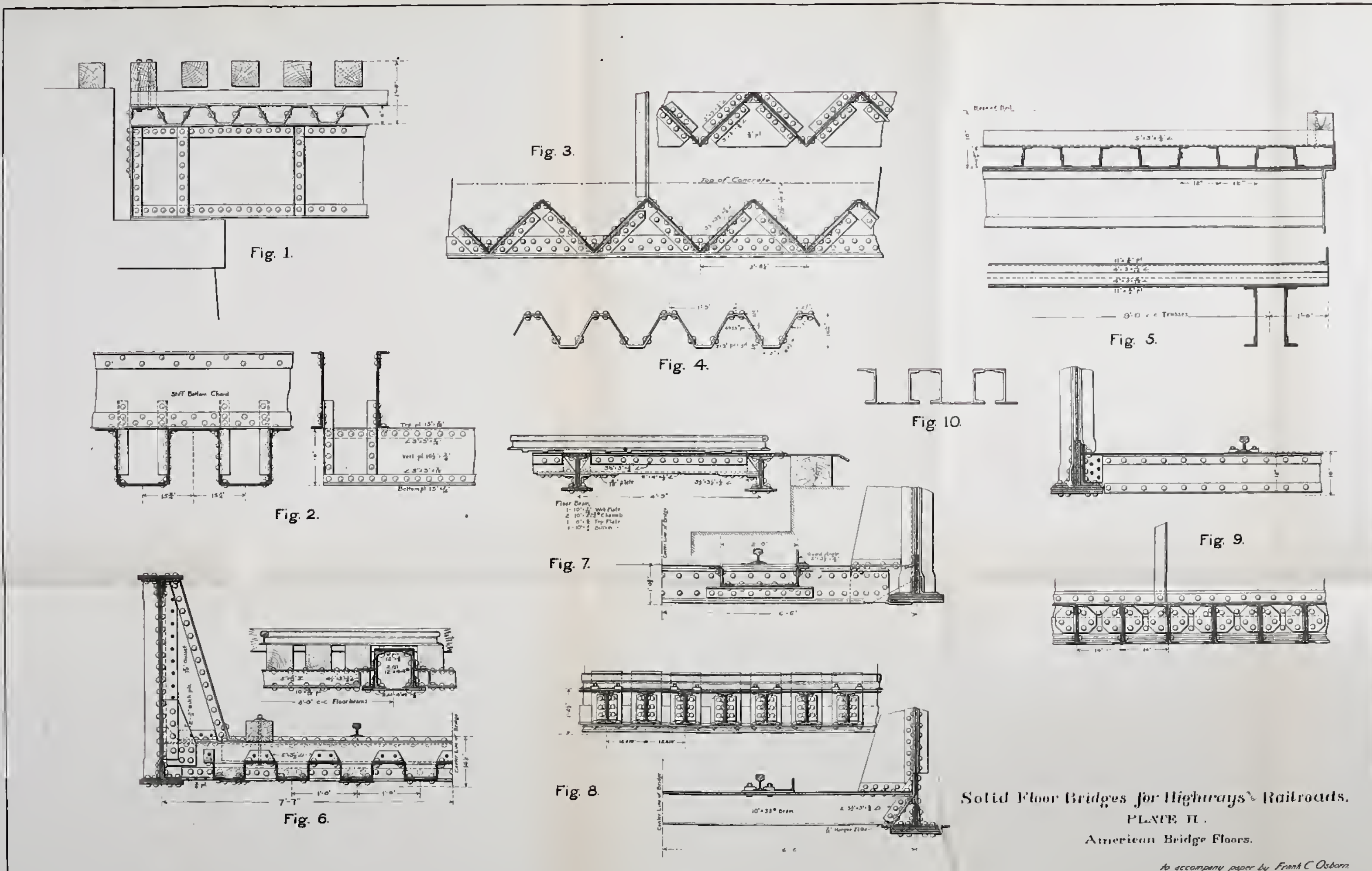
Of the designs illustrated, doubtless some are better suited for certain locations than others. The designer should thoroughly consider the particular case in hand, allowing, among other things, for the current prices of the various shapes, and giving due consideration to all the factors contributing to the excellence of his structure. Time will, in the future as in the past, undoubtedly bring about the "survival of the fittest."

As to highway bridge floors, there is less to be considered. European engineers are before us also in the use of solid floors for highway bridges, and most of the highway bridges of England are, and have been for many years, built with permanent floors. The forms in use are varied, plate iron, buckle plates, corrugated, and arched plates being mostly used, though some of the simpler forms of troughs are not infrequently met with. The trough form of bent plates used on the Tower Bridge, London, has already been mentioned. The highway bridge over the Tay, Scotland, has a similar floor. The Cobden Foue Bridge, at Southampton, has a floor of corrugated iron supported on shelf angles riveted to the floor beams, the shelf angles being curved to fit the crown of the roadway. The corrugated floor is of ¼-inch metal, and the corrugations are 6 inches deep, covered with concrete and wooden paving blocks.

In this country permanent floors are all of comparatively recent design. The Callowhill Street Bridge, over the Schuylkill River at Philadelphia, was built in 1875. Its floor is probably the earliest of the permanent kind built in America. It consists of square buckle plate flooring, riveted to light beam stringers at the sides and at the

FRANK C. OSBORI





Solid Floor Bridges for Highways & Railroads.

PLATE II.

American Bridge Floors.

To accompany paper by Frank C. Osborn.

ends to T-bars which cross the beams. The buckle plates are 3 feet square and ¼ inch thick with a total rise of 2½ inches. The bridge was built by the Keystone Bridge Co., and the plates manufactured for it are probably the first made in this country.

A ribbed steel arch bridge at East Rock Park, New Haven, Conn., was built about 1889 with a floor of ordinary floor-beams covered with creosoted pine plank 4 inches by 12 inches laid longitudinally, which was in turn covered with 3-inch by 12-inch creosoted pine planking laid transversely. Over this was laid a double thickness of tar-paper covered with a wearing surface of asphalt 2½ inches thick. The bridge proves very rigid and gives good satisfaction.

But even with all this care to obtain a stiff and permanent floor, its design is eclipsed by the paved floors on metal plates, which have since been used so often in spite of some opposition. The Carnegie Steel Co. have had a stock shape of curved plate flooring since 1882, which has been used in various cases.

In the summer of 1891, Mr. Carl Gaylor said in a paper before the Engineers' Club of St. Louis on "Viaducts across Railroad Tracks":

"In regard to floors, we have gone through the usual evolution from wooden joists and planking to wooden block pavement on planks carried by steel stringers. Permanent floors seem after all, on account of their great weight, to be a thing of the far future. As a step in this direction may be designated the covering of the Forest Park Boulevard Bridge over the Wabash tracks with Portland cement concrete arches between steel girders."

The Baltimore Street Bridge at Cumberland, Md., two plate girder spans 72 feet long each, has a floor consisting of cross girders riveted to the main girders and spaced 14 feet 5 inches apart. These support three lines of stringers, which divide the space between the girders into four openings about 6½ feet wide. Upon the stringers is laid No. 210 Pencoyd corrugated flooring and a layer of concrete is filled in on this to a depth of 7 inches. Upon the concrete a 2½-inch layer of Trinidad asphalt forms a wearing surface.

In 1892, when the grade crossing question was being studied in Buffalo, consideration was given to buckle plate form, and in a letter describing it at that time, Mr. Henry Goldmark said:

"This shape of iron has only recently been introduced into this country and I believe only two firms, viz., the Keystone and Pencoyd, have the dies for making the buckles. There is, however, no patent for covering the device, and for any larger piece of work, I fancy other mills would put in the plant necessary to make them. The buckle itself varies from 2 feet 9 inches to 3 feet 9 inches in width and is made in some three or four intermediate sizes, all the buckles being square. The flat

part at the edge of the buckles (through which the rivets pass) can be made of varying widths, from 2 inches or 3 inches to perhaps 6 inches wide. This gives a fair amount of variation in spacing the longitudinal stringers carrying the plates. As to the depth of floor, the tops of the stringers can be made to coincide with the top of the floor beam so that the depth of the floor beam governs the depth of the entire floor. I think a pretty good floor can be built with as little as 6 inches of covering (concrete and asphalt) over the tops of the stringers. This gives 3 inches or 4 inches over the top of the buckle. I do not think that we ought to have any less."

In making the first statement above, Mr. Goldmark very probably referred to buckled plates with three buckles in each plate, as now so generally used; for, as noted in the description of the Callowhill Street Bridge, buckled plates having one buckle to each plate were manufactured by the Keystone Bridge Company as early as 1875.

Since then buckle plates have been used very frequently. Three prominent cases are, the Walnut Street Bridge over the Schuylkill River, Philadelphia, where buckle plates $\frac{3}{8}$ inch thick are used, supporting a concrete and granite block pavement; the Front Street Viaduct at Columbus, Ohio, where the buckle-plate flooring is covered with concrete, sand, and brick pavement; and the Selby Avenue Bridge at St. Paul, Minn., on which buckle plates are used only at the cable-car tracks in the middle of the roadway, covered with concrete and pine blocks.

The investigation of the grade crossing question in Buffalo is very interesting. A number of different designs were considered and sketches representing the same are shown on Plate III, Figs. 1 to 5. Mr. George E. Mann, Chief Engineer Grade Crossing Commission, has very kindly furnished the writer with these sketches and data concerning the same. The floor adopted for this work was Pennsylvania Steel Company's Section, Fig. 4. The merits of this floor over the others, as found by the Board of Commissioners, are as follows :

First. Its form of construction, giving lateral rigidity, vertical stability to the floor beams, and moderate weight per square foot of area in the required limit of depth.

Second. For an asphalt surface the form of trough was considered better to hold the "binder" against the tendency of rolling forward under wheel-action in extremes of high temperature than either forms 1 or 5.

Third. Its cost compared with other forms of floor.

The width between bridge trusses is 42 feet and the depth of floor 2 feet 2 inches. For such a length of floor beam with this shallow limit of depth, it was considered unwise to adopt either plans 2 or 3,

owing to their increased weight and so necessarily requiring heavier and more expensive trusses.

Mr. Mann is of the opinion, however, that with greater depth of floor allowable and shorter distance between trusses, the concrete or the Melan arch plans (Figs. 2 and 3) are excellent. The following table gives a comparison of these several sections:

No.	Description of System supporting Floors.	Dead Load per sq. ft. of Floor.	Total cost per sq. ft.
1.	—Section M 31, Carnegie Steel Co. . .	85	$1.85
2.	—Melan Arches	190	2.00
3.	—Concrete	250	2.78
4.	—Troughs, Penna. Steel Co.'s Section	100	2.00
5.	—Buckle Plates	76	1.76

All metal work assumed for comparison @ 3 cents per pound in place.

An interesting solid floor was built on the 180 feet arch span Foot Bridge across the "Lagoon" in Lincoln Park, Chicago, in 1894, W. L. Stebbings, engineer. The floor beams are placed at panel points 18 feet apart, there being at the center of the span two beams placed near together with the expansion joint between them. Beginning at each of these center beams, a series of two groups of four steel wires each is carried back over the intermediate floor beams towards each end of the span. The vertical planes passing through these groups are 1 foot apart, horizontally in a direction transversely across the bridge. These groups of wires are filled around with concrete covered with 1 inch of granitoid top dressing.

Some time ago Mr. A. L. Schulz designed a floor for a highway bridge in Pittsburg, consisting of 8-inch channels laid flatwise, resting on the edges of the flanges, making a continuous flat deck, the flanges giving the vertical stiffness.

Corresponding to the practice of some of the railways of introducing masonry arches to obtain uninterrupted road-bed over waterways and other openings, a number of localities have recently had constructed arches of the Melan type, which system has been introduced by Mr. Fr. Von Emperger, of New York and Vienna. This system involves the bedding of a series of longitudinal I-beams in the intrados of an arch of concrete, the ends of the beams passing into and being entirely surrounded by the concrete of the arch abutments. This plan makes the use of any kind of paving a very simple matter, and the construction permits of obtaining ornamentation and architectural effect at comparatively slight extra cost. Mr. Von Emperger also favors the use of similar concrete and I-beam arches between floor beams on steel bridges, claiming for this form: freedom from necessary care and frequent painting of metal surfaces, great strength and stiffness, and 30 per cent. less cost than the use of Carnegie's curved plate form for the same span.

In closing, the writer submits herewith a sketch of the floor he designed during the past year for the South Rocky River Bridge, near Cleveland, O. (see Plate III, Fig. 6). This bridge is 1219 feet total length, center to center, and has a 32-foot roadway, with provisions for a double track electric railway line. It will be noticed in this bridge that the buckle-plates are placed the other side up from the usual practice, thereby saving considerable weight of concrete filling and decreasing the thickness of the floor proper, while still preserving all the strength. The method of supporting the track stringers to preserve the crown of the roadway has proven very satisfactory. The drawing also shows, incidentally, the design adopted at the ends of the floor beam. Conditions required that, although no sidewalks were to be built immediately, provision should be made for their addition at some future time. The sidewalk brackets are, consequently, designed for a greater length, but are cut off in such a manner that about six feet more can be added to their length at any time by cutting off the curved end beyond the splices and splicing on a new section. While brick will be used for the pavement of this bridge, the design is just as well adapted to asphalt, granite, or wooden blocks.

The writer takes great pleasure in acknowledging here the valuable service rendered in the preparation of this paper by Mr. Bernard L. Green, who has conducted the correspondence, prepared the drawings, and written a large part of the text.

Acknowledgments are also due the following gentlemen who have kindly furnished drawings and given other information contributing to the value of the paper:

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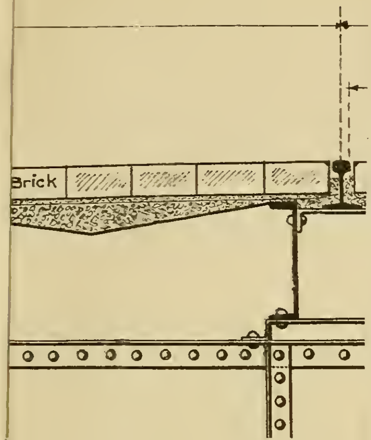
Mr. J. F. Wallace, Chf. Engr., I. C. R. R.
Mr. F. W. Wilson, Bridge Engr., N. Y. C. & H. R. R. R.

FRANK C. OSBORN.



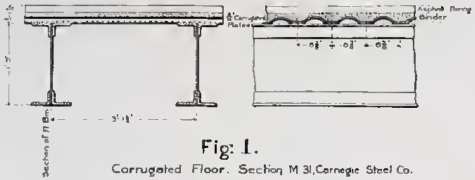


Fig: 1.
Corrugated Floor. Section M 31, Carnegie Steel Co.

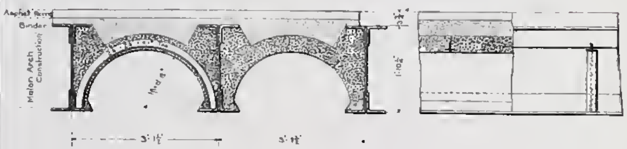


Fig: 2.
Melan Arch Construction

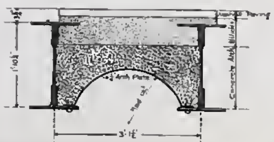


Fig: 3.
Concrete Arch.

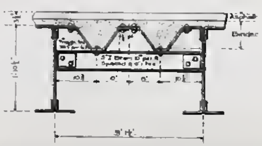


Fig: 4.
Trough Floor, Penna Steel Co. Section

Fig: 5.
Buckle Plate Floor.

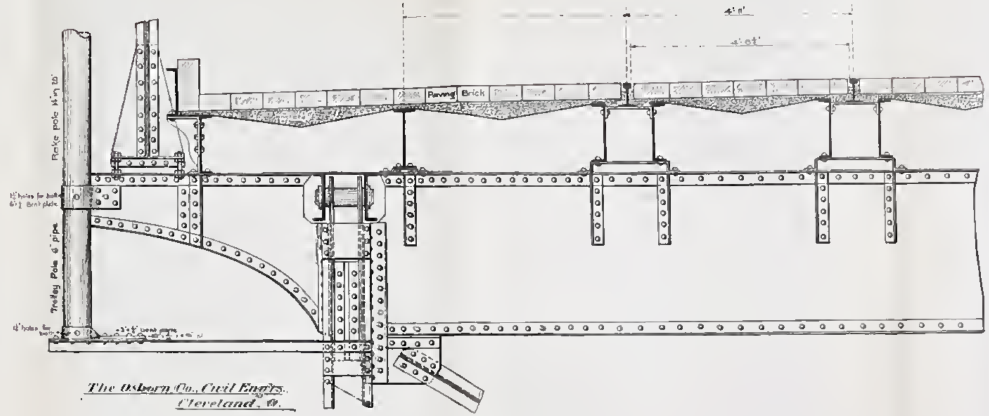


Fig: 6.
South Rocky River Bridge.
Cleveland Ohio.

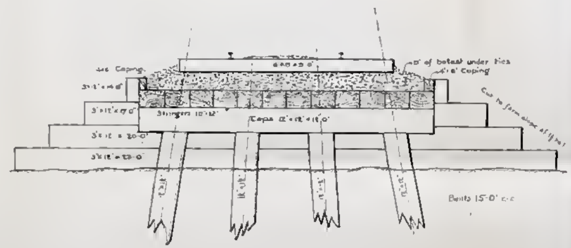


Fig: 7.
Ballasted Trestle, Southern Pacific Co.

Solid Floor Bridges for Highways & Railways.
PLATE III.
Highway Bridge & Trestle Floors.

to accompany paper by Frank C. Osborn

VAN BUREN STREET ROLLING LIFT BRIDGE, CHICAGO, ILLS.

BY WARREN R. ROBERTS, CITY BRIDGE ENGINEER, MEMBER WESTERN SOCIETY OF ENGINEERS.

[Read before the Society, March 20, 1895.*]

INTRODUCTION.

WITH the opening of the new bridge, over the South Branch, at Van Buren Street, a work was completed which had caused the engineers and contractors a great deal of care and anxiety in its construction and not a little solicitude as to its success. There were many difficulties to be overcome both in the design and in the construction of this bridge. Its completion and successful operation indicate that these difficulties were overcome, not to say that this bridge cannot be improved upon. This was the first bridge made from this design, which fact is sufficient reason why improvements should be made if a second one were to be built.

The design of bridges, and especially of movable bridges, has passed through a state of evolution. The common swing bridge has reached its present state of perfection by a process of development, due to which fact it is, no doubt, the most desirable type of drawbridge. Whenever an engineer selects a bridge of new design, he must be willing to pay for the general good to be derived from the introduction of the new type.

Before beginning the consideration of this Rolling Lift Bridge, the conditions to be fulfilled at the bridge site and the governing requirements should be stated, for it may be assumed that under conditions favorable to the swing bridge no other type would have been considered.

CONDITIONS AND REQUIREMENTS.

The old bridge at this site was a swing bridge giving two channels, an east one of about 55 feet, and a west one of about 60 feet. The east channel was the one principally used, the west one being too shallow and crooked to be navigated by anything except tugs and other small craft. This old bridge was only 34 feet wide over all, having one roadway of 20 feet and two sidewalks of 7 feet each.

The first bridge considered for replacing this old draw was a swing bridge, with equal arms of 110 feet each, giving a clear channel on the east of 67 feet and on the west of 55 feet. The total width of this pro-

* Manuscript received December 14, 1895.—*Secretary, Ass'n of Eng. Socs.*

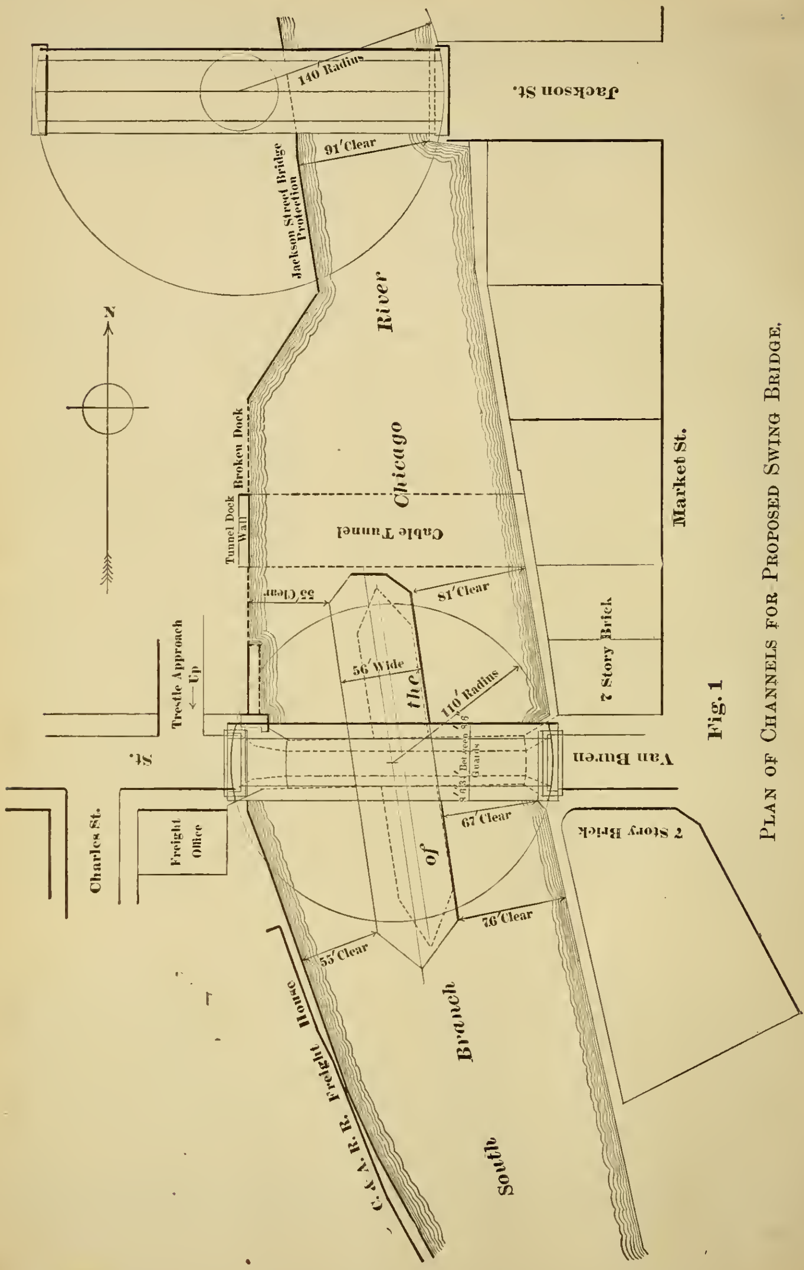


Fig. 1

Plan of Channels for Proposed Swing Bridge.

posed bridge was 51 feet, having one roadway of 34 feet, and two sidewalks of 8 feet 6 inches each. The east channel was thus increased from 55 feet to 67 feet, and the west reduced from 60 feet to 55 feet, with an increased width of bridge of 17 feet. To accomplish this it was intended to move each abutment back a considerable distance. This change of channels, location of abutments, etc., is clearly shown in Fig. 1. The old bridge and protection are shown in broken lines and the proposed bridge in full lines.

At the time these changes were being considered, the Metropolitan Westside Elevated Railroad Company was considering means and methods of crossing the river, and it was proposed by the city to make this swing bridge a double-deck structure, with a roadway below and the elevated railway above. But this plan for a swing bridge was abandoned for the reason that a straight channel was insisted upon by the United States Government, from Jackson Street Bridge to the turn in the river below Van Buren Street, with the clear width of this channel of not less than 100 feet. Such a channel could not be obtained by means of a swing bridge, without placing the center pier considerably to the west and making the draw much longer, which was not practicable on account of damages to the adjoining property.

Several other schemes, some for a combined bridge and others for separate bridges, were considered, but none of them fulfilled all the requirements.

It was while engaged upon an investigation and elaboration of certain of these schemes for the Metropolitan Railway, that Mr. William Scherzer devised the type of bridge we are considering. After a careful investigation of its merits, as compared with those of other types of lift bridges, it was decided by the management of the Metropolitan Company to adopt this bridge, and Mr. Scherzer was entrusted with the preparation of the detail plans. The Metropolitan Company then proposed to the city that this type of bridge be used at Van Buren Street, and that they be allowed to cross the river between Jackson Street and Van Buren Street on a similar bridge. This proposition was accepted by the city (and approved by the Secretary of War, November 16, 1893), and the bridge at Van Buren Street was constructed from Mr. Scherzer's design.

The two points of merit which this bridge possesses, and which make it especially suitable for the place are: First, that it moves in a vertical plane, thereby giving room for it, the Jackson Street draw, and for the Metropolitan bridge, which are all in close proximity; and second, having no center pier, the clear channel of 91 feet at Jackson Street is maintained at Van Buren Street. The channel at this place and the present location of the bridges are shown in Fig. 2.

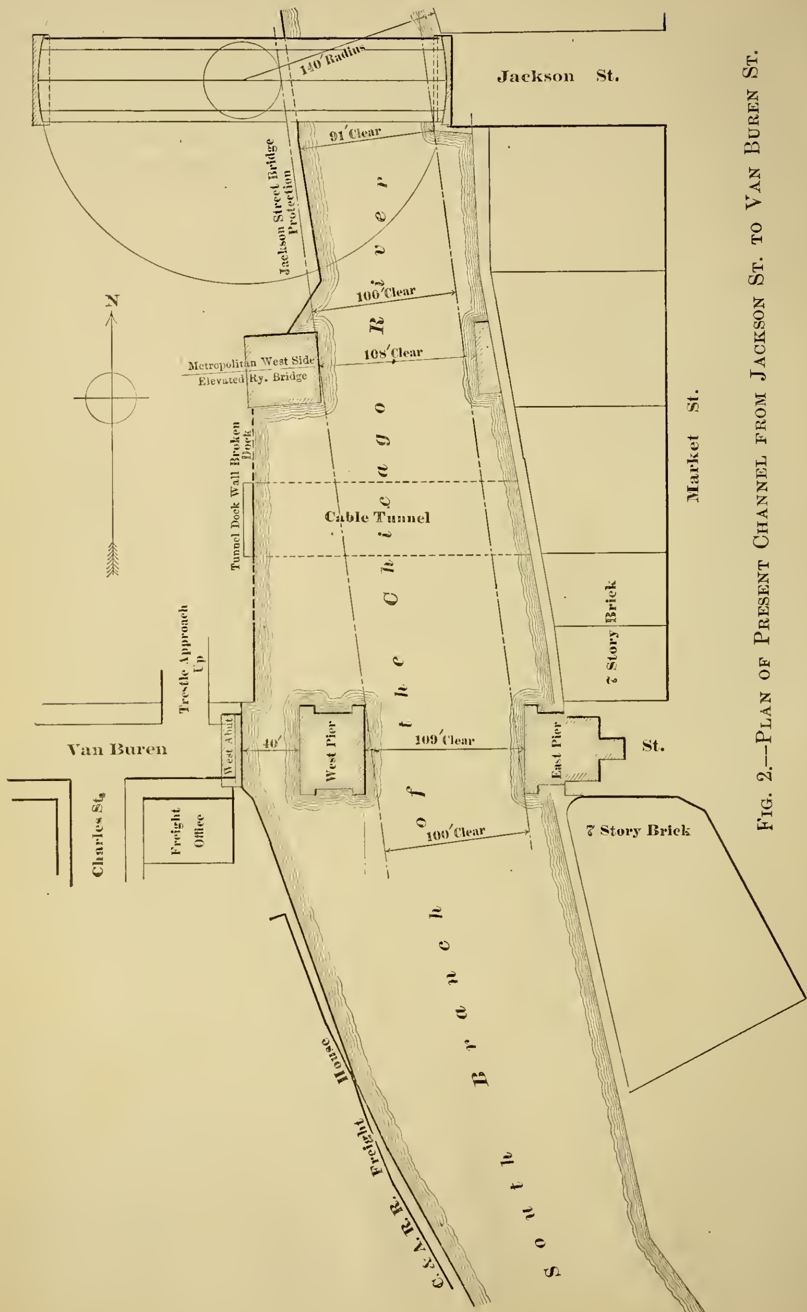


FIG. 2.—PLAN OF PRESENT CHANNEL FROM JACKSON ST. TO VAN BUREN ST.

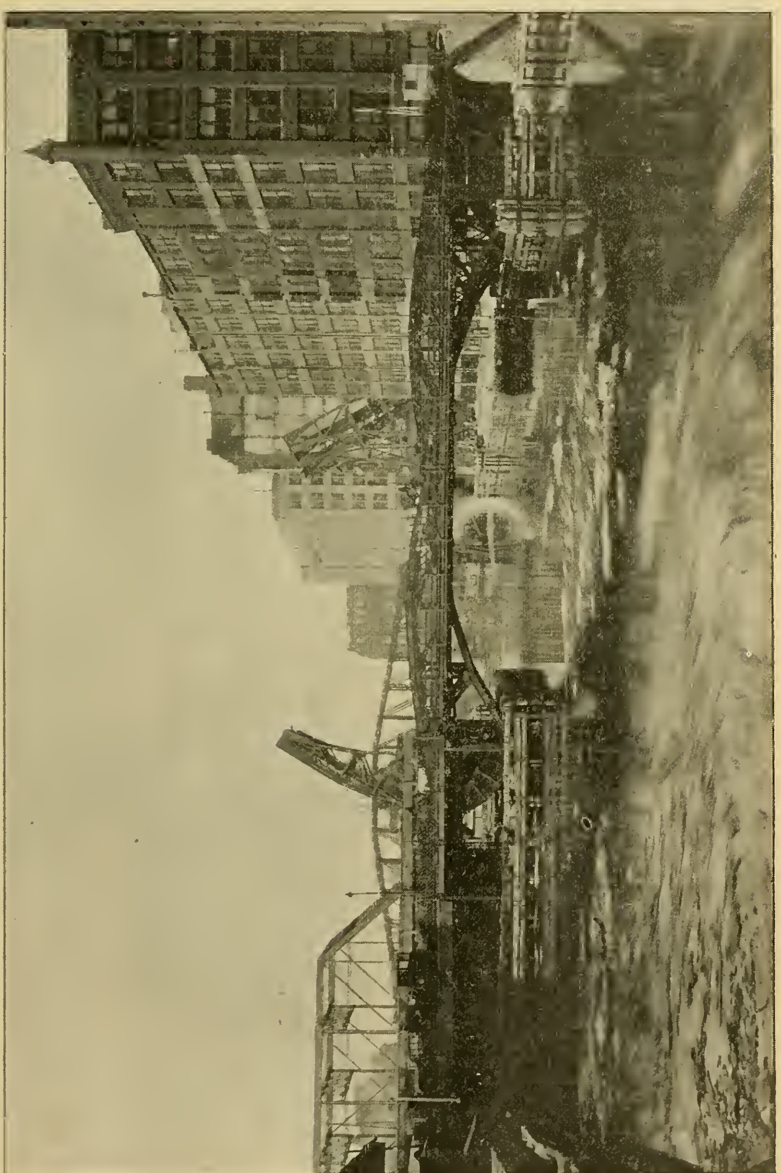


FIG. 3.

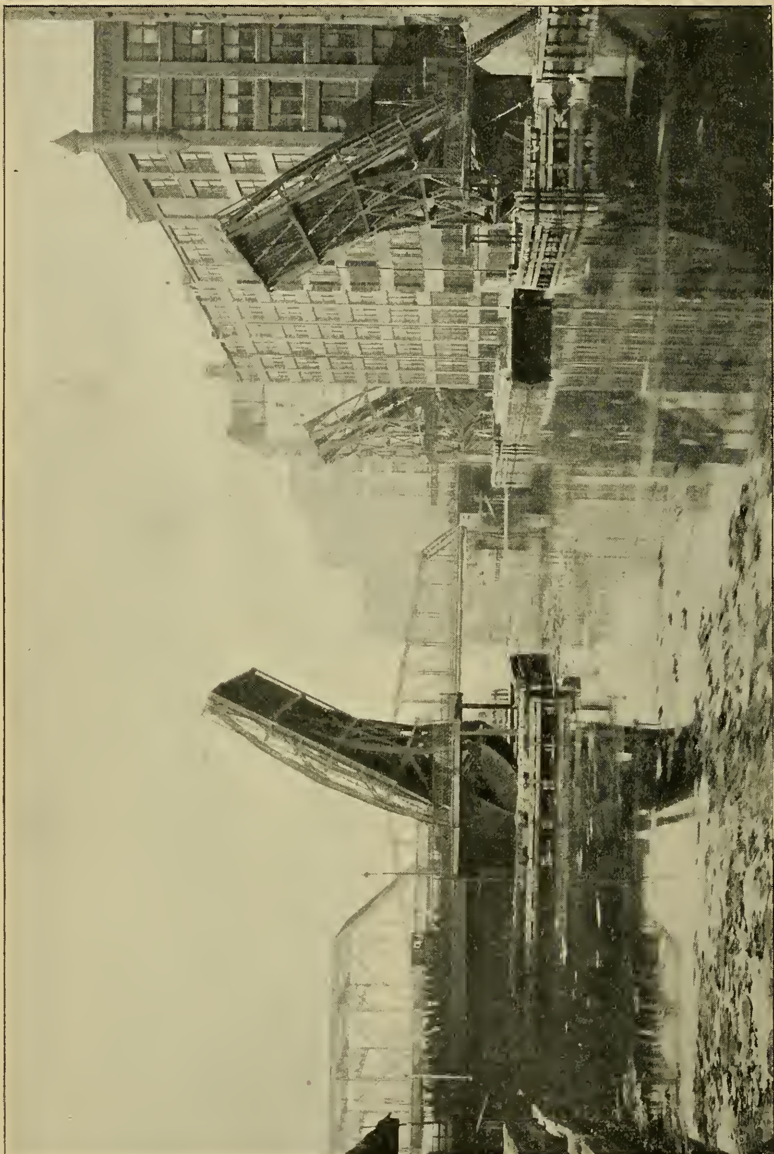


Fig. 4.

GENERAL DESCRIPTION.

The peculiar motion of the bridge in operation has given it the name of "rolling-lift" bridge; each half of the bridge rolling backward and upward upon three segmental girders at its base.

Fig. 3 shows the bridge closed, ready for traffic. This illustration was produced from a photograph of the bridge, taken after completion, and correctly represents the bridge. The two movable parts of the bridge are in every respect alike. The approaches are not alike. On the west the abutment and pier are separated by 40 feet, and the space between these is bridged over with plate girders and forms a room for the machinery and motors. On the east side the abutment and pier are combined in one piece of masonry, and space for the machinery was provided by building a room in the abutment. In each of these rooms are placed the motors, air pumps, air reservoirs, and other machinery necessary for the operation of one-half of the bridge; *and each half is operated independently of the other.*

On each approach, on top of the center roadway girder, is placed an operator's house. The operator has here before him the air valves for operating the gates, signals and brakes, the controller for operating the motors, and other apparatus for the complete control of one-half of the bridge.

Fig. 4 shows the bridge open, giving a clear channel of about 100 feet between abutments. The time required for opening the bridge is about thirty-five seconds, and for closing about twenty-five seconds, which time could be reduced if it were desirable. In this view the Metropolitan Railway "rolling-lift" bridge, and Jackson Street swing bridge are both shown in the background.

In Fig. 5 is given a side elevation of the west half of the bridge when open, showing very clearly the position of the segmental girders for this position of the bridge. A study of this view will help to understand the peculiar motion of the bridge. It will be seen that there is no sliding motion, and no hinge motion, as is generally expected by those seeing the bridge in operation. It is a true rolling motion, with no friction, except rolling friction, and the friction at the pin connection of the operating strut and possibly a little in the meshing of the racks under the segmental girders.

Fig. 6 gives a view looking east upon the west half of the bridge when open. We have here very forcibly presented the amount of wind-surface offered when the bridge is fully opened. The area above the line of the roadway amounts to about 3,300 square feet, and a pressure of 18 pounds per square foot gives a pull in the operating strut of 165,000 pounds.

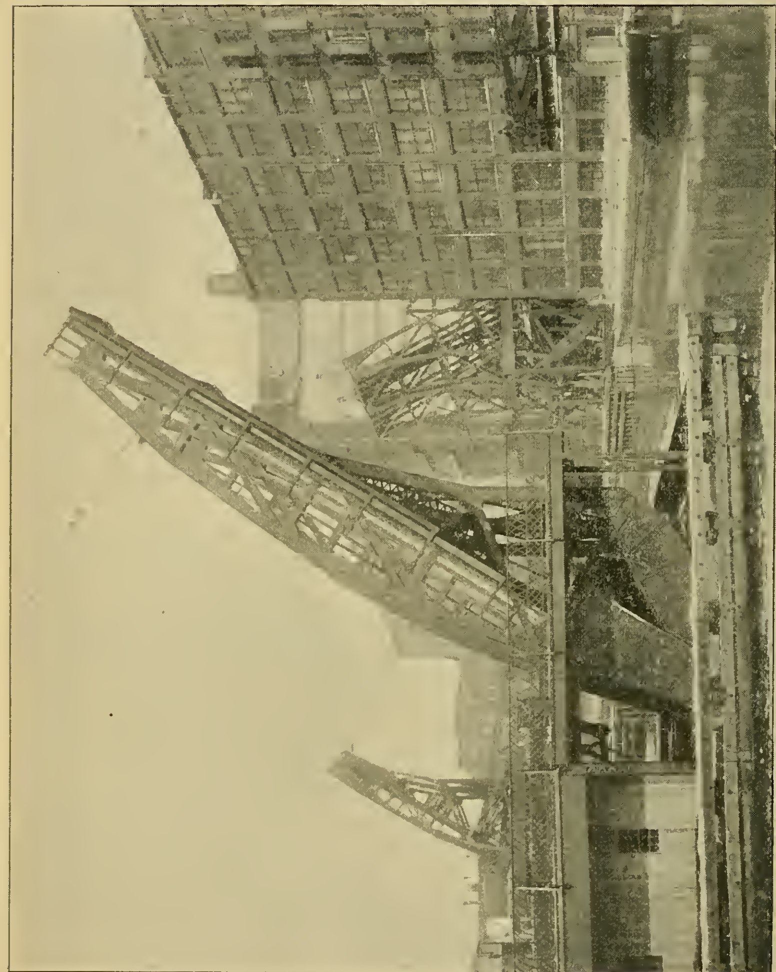


Fig. 5.

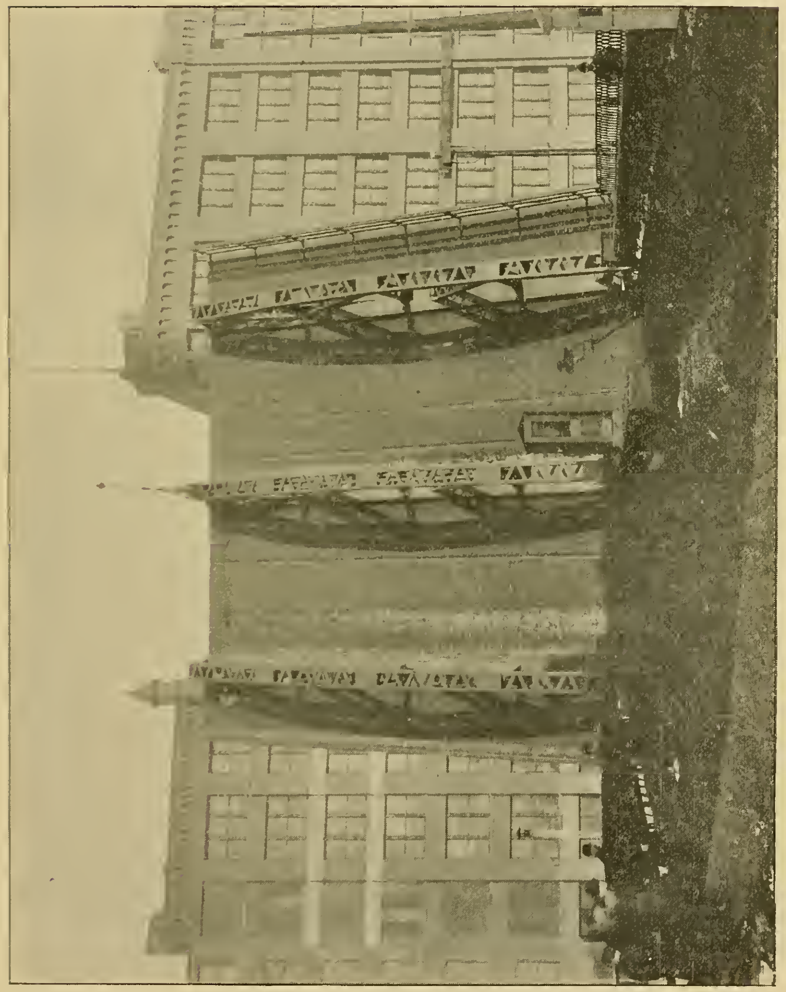


Fig. 6.

This is the maximum stress for which the operating strut and the machinery were figured; it being assumed that traffic on the river would stop with a wind which would give 18 pounds per square foot. Mr. Trautwine, in his "Pocket-Book," gives 18 pounds per square foot as corresponding to a violent storm of 60 miles per hour.

In Fig. 7 the horizontal bracing and the vertical bracing between the segmental girders are clearly shown. This vertical bracing and the lower panel of the horizontal bracing were not riveted up until both sides of the bridge were completed, lowered into a horizontal position and the adjustments made between the two parts.

The adjusting was one of the most interesting parts of the erection. When the bridge was first lowered into a horizontal position, so that the two parts of the north truss came together properly, it was found that the east half of the center truss was an inch or more above the other half, and that the east half of the south truss was some two inches or more above the west half. The two parts of all three trusses were brought into the same plane by the adjustments under the tail girders, and the vertical bracing was then riveted up.

At the time this vertical adjustment was made there was also a lateral error of about the same amount, the ends of the trusses on the east portion coming about 1 to 1½ inches too far north to match those of the west portion. The two parts are raised, and a transit told us that the trusses in the west portion stood very nearly in vertical planes, while those of the east portion leaned about 1 to 1½ inches to the north. Therefore we riveted the lateral bracing in the west portion as it stood. The upper end of the east portion was then pulled over 2 inches to the south by attaching cables to the upper and middle parts of the trusses, and the lateral bracing was riveted while the cables were attached. When the cables were released and the two parts again lowered, they came together perfectly.

SUBSTRUCTURE.

The construction for each of the three parts of the substructure was essentially the same; the foundation being formed of piles, the body of the structure of concrete and the top of Bedford masonry.

The foundation piles were driven about 3 feet centers over the entire area to be occupied by each piece of masonry. These piles were of Norway pine, 50 feet long and not less than 10 inches in diameter at the small end. They were driven nearly to the water line and sawed off 17 feet below it, leaving 33 feet of the piles in the foundation. The west abutment was built first, then the west pier, and lastly the east pier and abutment. While the driving of the piles for each part was progressing, the caisson for the same part was being built at dock

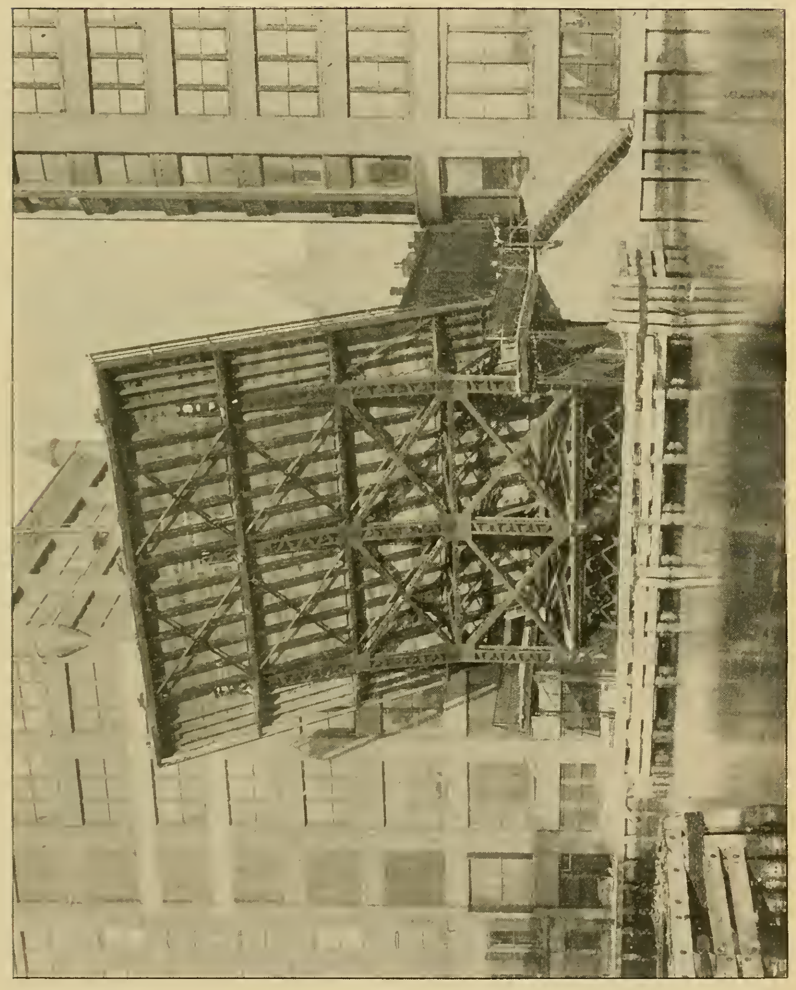


FIG. 7.

and, when partially filled with concrete, was floated into position. The concreting was then continued, and the sides of the caisson were continually built up to keep progress with its sinking until it came to a bearing on the piles. The concrete used was machine mixed, with one part of Portland cement, and two and one-half parts of sand and five parts of broken limestone.

The first work done on the west abutment was to construct the coffer-dam and connect it at each end with the dock. (See Fig. 8.)

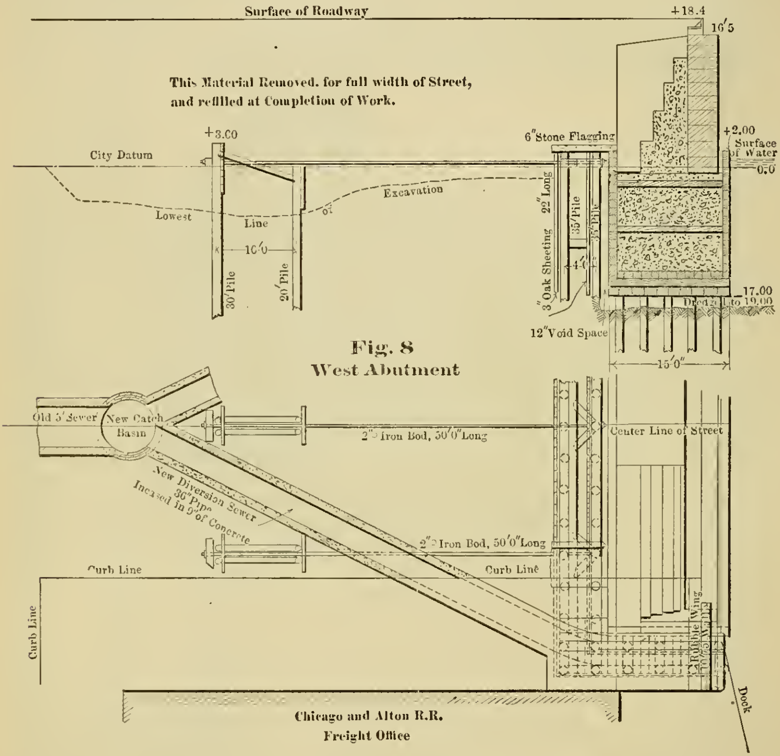
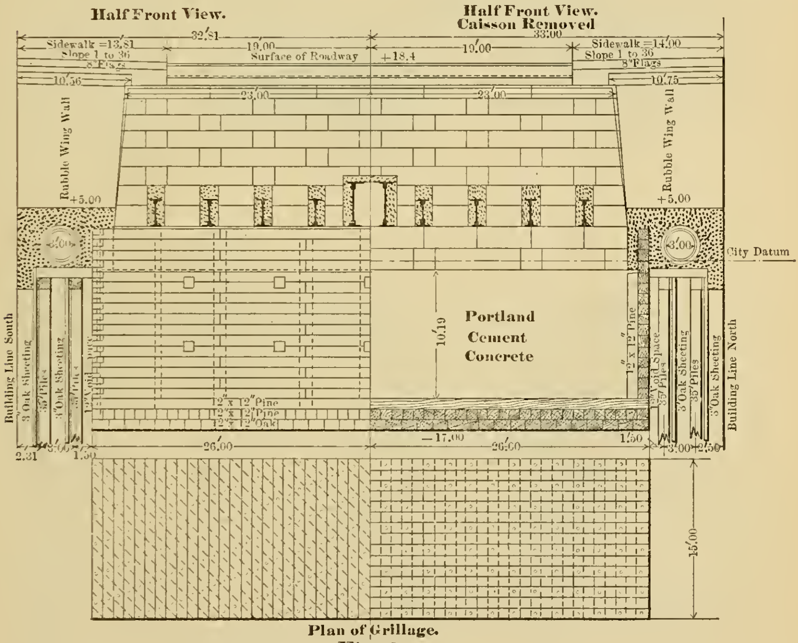


Fig. 8
West Abutment

This coffer-dam was then anchored back with three 2 inch anchor rods to piles driven about 50 feet to the rear. These anchors were to prevent the earth filling from forcing the coffer-dam towards the river when the excavating for the abutment was done. They proved only partially successful in this office. A sewer 5 feet in diameter emptied into the river on the center line of Van Buren Street. This sewer was divided into two sewers, each 3 feet in diameter, and passed around the ends of the abutment as shown in the illustration.

In Fig. 9 is given a front elevation of the west abutment, showing the pockets that receive the girders which form the floor for the west machinery room, previously mentioned.

In the plan of the west pier (Fig. 10) are shown the pockets formed to receive the tail girders when the bridge is open. Besides these pockets the pier contains two large chambers built in to save masonry. In one of these chambers a sump was made and in it placed a centrifugal pump driven by a small motor placed on the pier above. This pump is controlled from the operator's house and run whenever necessary to remove the water which leaks in through the concrete. In this plan



West Abutment Fig. 9

is also shown (by the broken lines) the location of the cast steel racks upon which the segmental girders revolve. The sections of the pier (Fig. 11) show the depth and form of the pockets mentioned above. In these sections is also shown the anchorage for the tail girders, which will be referred to again.

The east pier and abutment, although completed as one piece of masonry, were constructed separately. The abutment and east half of the pier, as originally designed, came between two seven-story buildings, with foundations extending into the street. The excavation for the pier

Cross Section at B-B

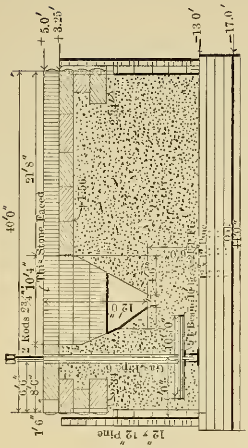
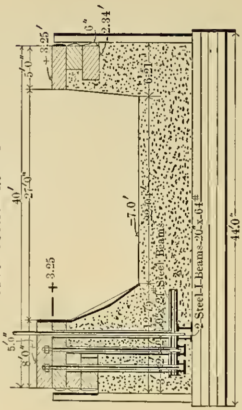


Fig. 11. West Pier.

Cross Section at C-C



Half Front Elevation of Pier. Half Front Elevation, Caisson Removed.

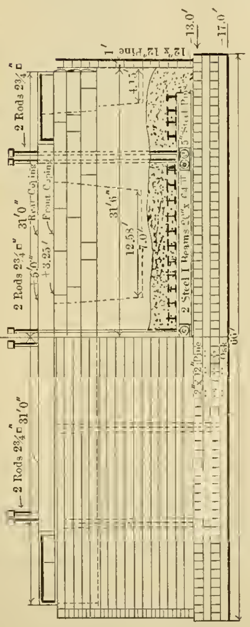
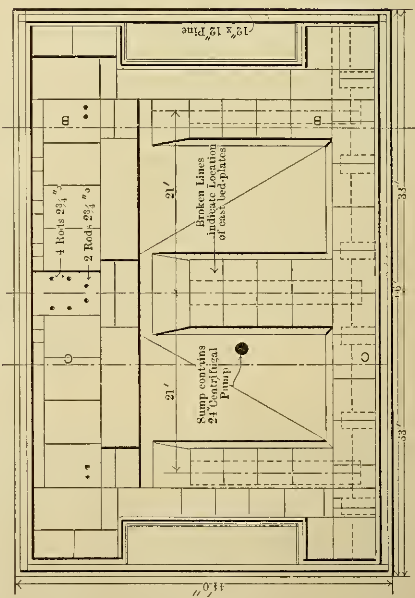


Fig. 10. West Pier.

Plan of Pier.



came considerably below these foundations. This being the case the contractor preferred to reduce the width of the pier, which was to be sunk with an open caisson, and increase the width of the abutment, which was to be put in by a coffer-dam. Therefore the piling for the coffer-dam, shown in the section of the abutment (Fig. 12) was moved west about 18 feet or a little beyond the west face of the buildings.

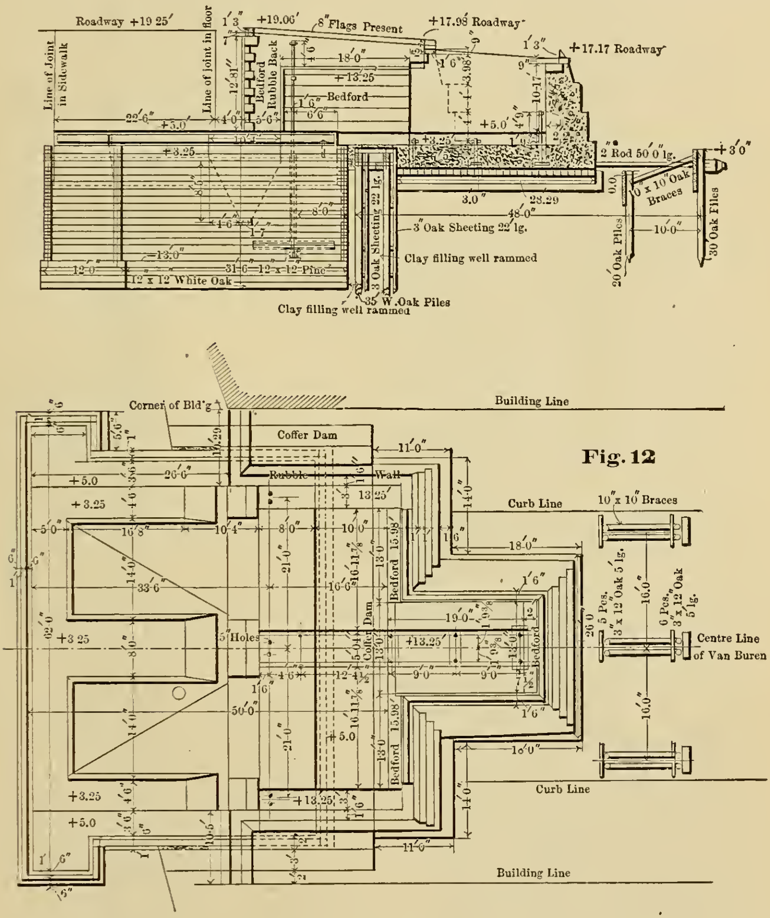


Fig. 12

That portion lying between the buildings was then excavated dry, thereby insuring more protection to the foundations of the buildings during the progress of the work.

SUPERSTRUCTURE.

The moving part of the bridge may be considered as divided into

three spans: the river span and two anchor spans. The river span, which has the appearance of a low arch (See Fig. 13), is composed of two cantilever arms, there being no bearing at the center between the two parts of each truss. The clear headroom above the water for the four middle panels is about 16 feet. The river span is 115 feet center to center of bearings. The anchor spans are each 30 feet 6 inches center to center of columns, and consist of two parts: the movable part from *A* to *Y* (Fig. 13), and the fixed part from *Y* to *G*. These two parts are held firmly together at *Y* by hangers passing beneath the tail girders.

Within these tail girders and between them, in the two end panels, are placed the counterweights for balancing the cantilever arms. These counterweights consist of cast iron; the total amount required for one side being about 129 tons. The exact amount of this counterweight was decided upon after the bridge was in operation. Sufficient weight was added to prevent the bridge from coming to a horizontal position when freely lowered by the brakes. The bridge, when so lowered, comes to a rest a little above the horizontal; the power is then applied and the motors force the bridge down to a level.

The floor on the draw consists of two courses of planking, each laid transversely to the length of the bridge. On the roadways the lower course is of 3½-inch pine, each plank being held to the flanges of each I-beam by two 3½ inch by ⅜ inch railroad spikes, driven from below. The upper course on the roadway is of 3-inch oak plank and is thoroughly spiked to the lower course with 6-inch spikes. The lower course on the sidewalks is of white pine, dressed to 1¾-inch, securely spiked to the I-beams and wooden joists. The upper course is of 4-inch by 1½-inch dressed and matched Georgia pine, and extends through the trusses to the wheel guard.

A uniform quality of open-hearth steel was used throughout the work, in which the average phosphorous limit was .06 per cent. for "acid steel" and .025 for "basic steel." When tested in specimens, cut from the finished plates and shapes, of not less than ½ square inch in section, an ultimate strength of from 60,000 to 68,000 pounds per square inch was required, with an elastic limit of not less than one-half the ultimate strength, with an elongation of at least 26 per cent. in 8 inches, and a reduction at point of fracture of at least 50 per cent. It must also, when cold, bend flat upon itself without sign of fracture, and be capable of withstanding the usual punching and drifting tests.

In Fig. 14 is shown a quarter plan of the draw span. The sidewalk on the approach joins that of the draw at *S*, while the junction between the corresponding parts on the roadway is at *R*. When the bridge is raised the floor of the moving part of the roadway passes back of and beneath that on the approach, making it necessary to bring

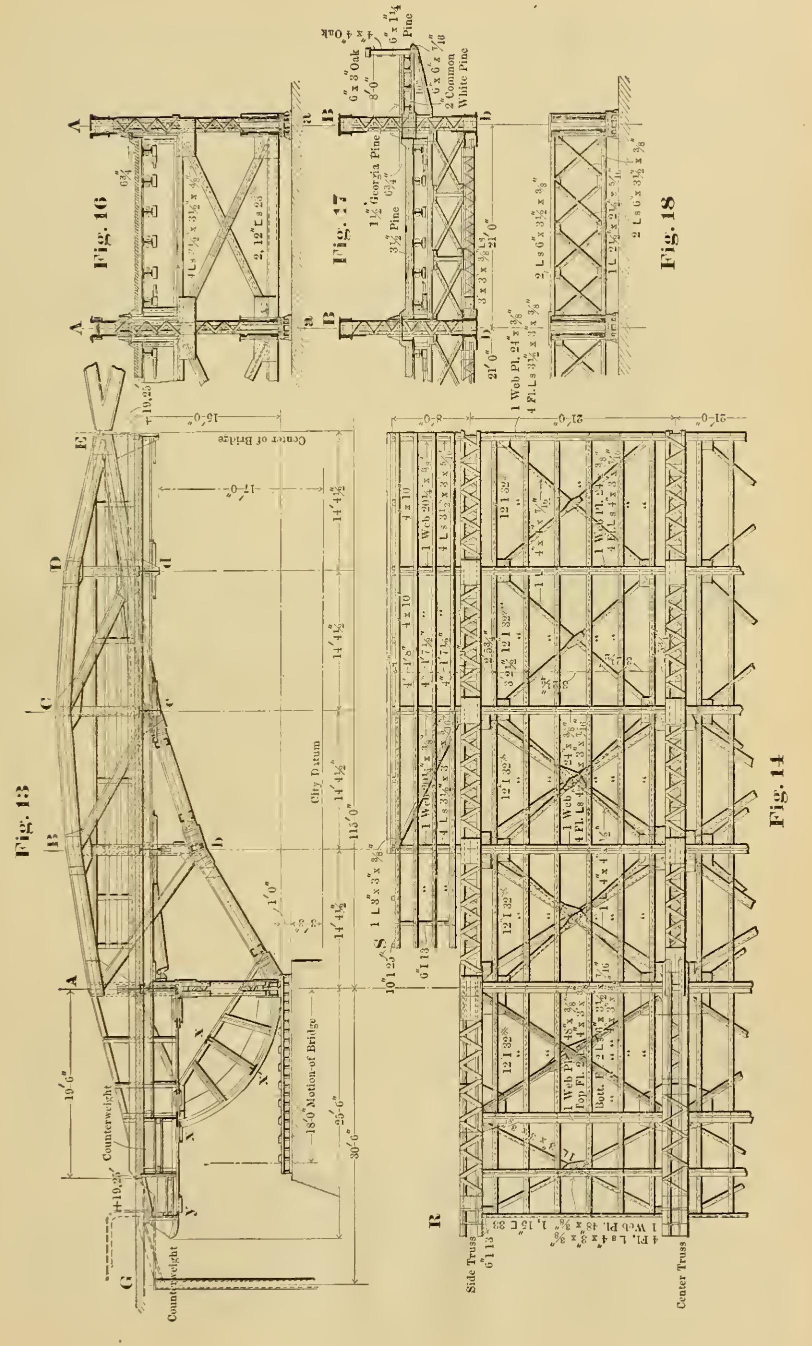


Fig. 13

Fig. 14

Fig. 16

Fig. 17

Fig. 18

the floor on the approach to a very thin edge to form a connection with the draw when the bridge is closed. The movement at the sidewalk is the reverse of the above; that is, the moving sidewalk passes above the fixed part when the bridge is raised. The method of making the connection between the floors of the moving and fixed parts is given in Fig. 15. In the castings for the roadway the part on the approach is brought out to a thin edge, while of those for the sidewalk the one on the draw is so drawn out. The movement at the sidewalk is more nearly horizontal than at the roadway, and it was necessary to make the connection on the sidewalk with a ½-inch steel plate for a distance of 12 inches. This difference of movement between the roadway and the side-

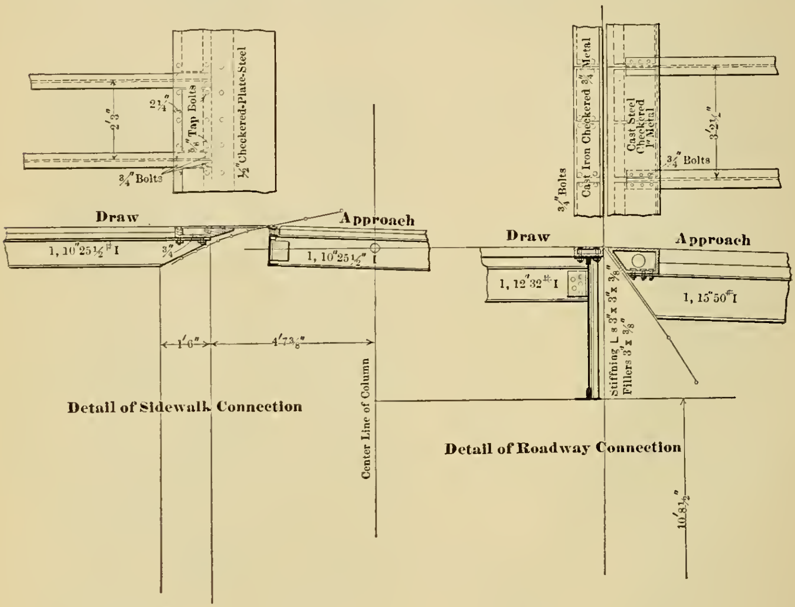


Fig. 15.

walk is due to the junction with the approach being made at points differing in relation to the center of motion, the junction for the sidewalk being in front of this center, and that for the roadway being behind it.

Figs. 16, 17 and 18 are sections at *A–a*, *B–b* and *X-x*[1] respectively and are given to show the bracing used at each place.

A detail of the tail girder, segmental girder and a part of the center truss is shown in Fig. 19. These girders are the same for the outside trusses, except that the pin connection for the operating strut (shown at *A*) is omitted, and the material in the girders of the outside trusses is

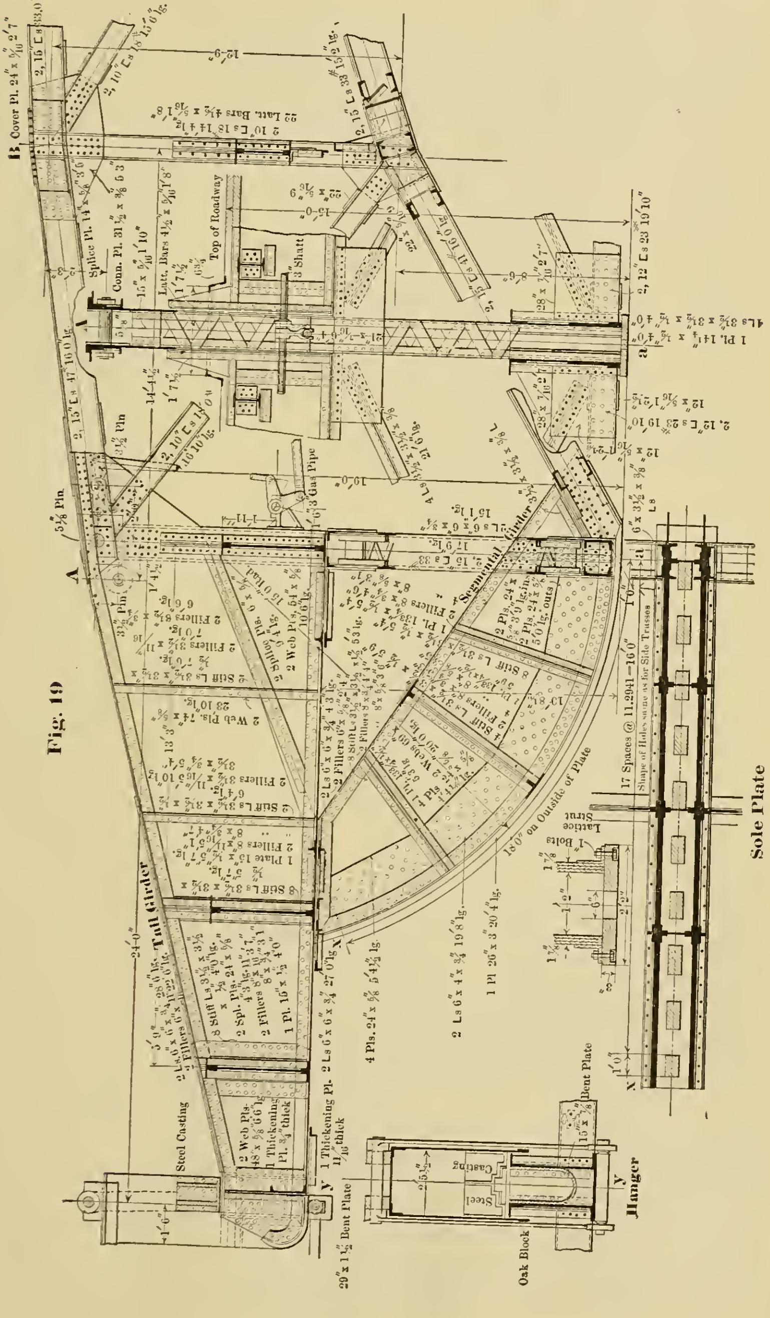

Tail Girder
Segmental Girder
Sole Plate
Hanger
Top of Roadway
Gas Pipe
Steel Casting
Oak Block
Bent Plate
Lattice Strut

Fig. 19

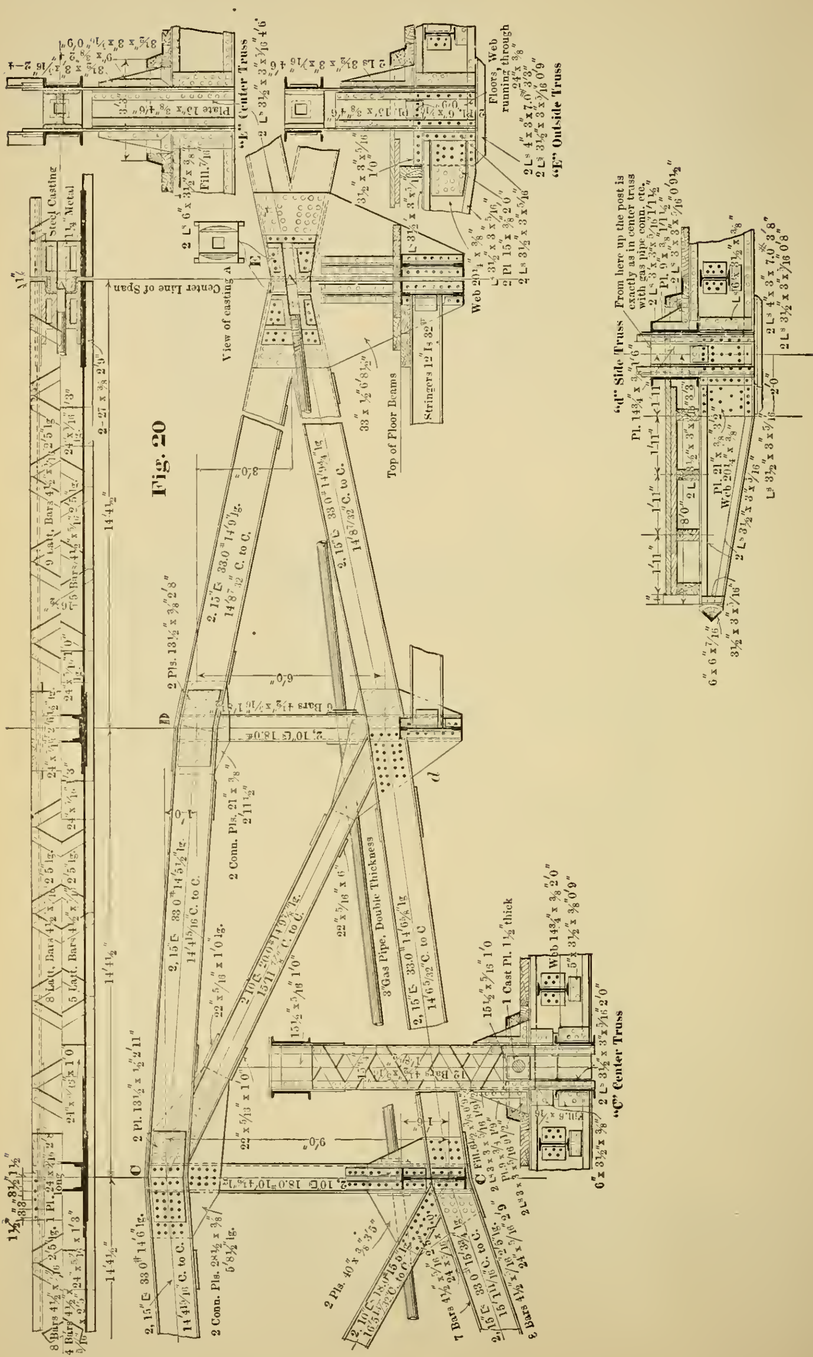

"L" Center Truss
"E" Outside Truss
View of casting A
Center Line of Span
Steel Casting
Top of Floor Beams
3" Gas Pipe, Double Thickness
"d" Side Truss
"C" Center Truss

Fig. 20

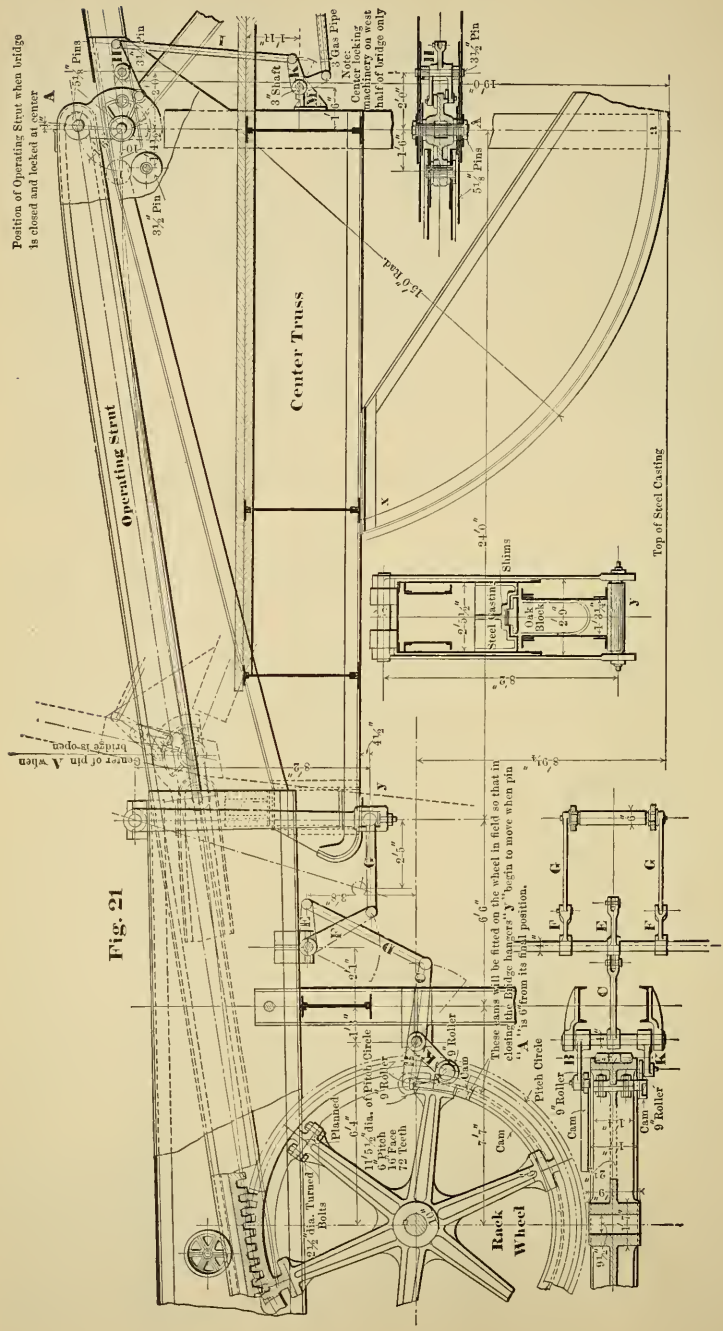
some lighter. On the bottom of the segmental girder is a steel track plate, 26 inches wide by 3 inches thick, and cut out, as shown in plan, so as to receive the teeth of the cast racks on the masonry, upon which these segmental girders revolve. This steel plate is securely bolted to the bottom flange of the segmental girder with one-inch bolts, in the manner shown in the section of the plate. At Y is shown the connection between the tail girder and the approach. When we have a sufficient load on the river span there is an upward pressure from this tail girder, which is received by the steel casting bolted into the end of the approach girder. With a load between A and the approach, the tail girder must be supported by the hanger at Y.

Fig. 20 gives the remaining portion of the truss and the center latch. The way in which the latch is operated is shown in Fig. 21. As stated before, there is no bearing at the center between the two parts of a truss. The only connection here is made by a pin latch, which is intended only to prevent lateral motion. This center latch is operated from the west side, and the locking apparatus is therefore omitted on the east side.

In Fig. 21 is given the method of applying the power to the bridge· From the machinery runs an operating strut joined to the center truss at A, as shown. Within this strut is a cast steel rack which engages with the rack wheel. In the position in which the strut is shown the bridge is closed and the latch at Y, and the pin latch at the center of the river span, are both in the position shown, and the bridge is locked, ready for traffic. When the bridge is open the cam at A has moved to the location indicated by the broken lines. In the first movement of the strut backward, the cam crank at A is revolved one quarter of a revolution, and acting on the cranks and levers shown, withdraws the pin latch at the center of the bridge. At the time this movement is taking place, a small roller strikes the cam on the rack wheel, and acting on the connecting levers, withdraws the tail girder latch at Y. These two duties performed, the bridge is free to move, and the succeeding movement of the operating strut begins to raise the bridge. These movements are simply reversed when the bridge is being closed and locked. The power to raise one-half the bridge is applied through one operating strut and carried to the two outside trusses by heavy bracing between them at panel point A.

The vertical adjusting, already referred to for bringing the two parts of a truss into the same plane, is shown in this illustration (Fig. 21). By increasing or decreasing the shims between the castings on the end of the tail girder and that on the approach girder, the center end of the truss could be raised or lowered.

The two approaches being of a similar construction, the west one


Position of Operating Strut when bridge is closed and locked at center
Operating Strut
Center Truss
15′-0″ Rad.
3″ Shaft
3″ Gas Pipe
Note: Center locking machinery on west half of bridge only
3½″ Pin
5⅛″ Pins
Top of Steel Casting
Shims
Steel Casting
Oak Block
Center of pin A when bridge is open
These cams will be fitted on the wheel in field so that in closing the Bridge hangers "y" begin to move when pin "A" is 6″ from its final position.
9″ Roller
Cam
Pitch Circle
Planned
2½″ dia. Turned Bolts
11′5½″ dia. of Pitch Circle
6″ Pitch
16″ Face
72 Teeth
Rack Wheel
Fig. 21

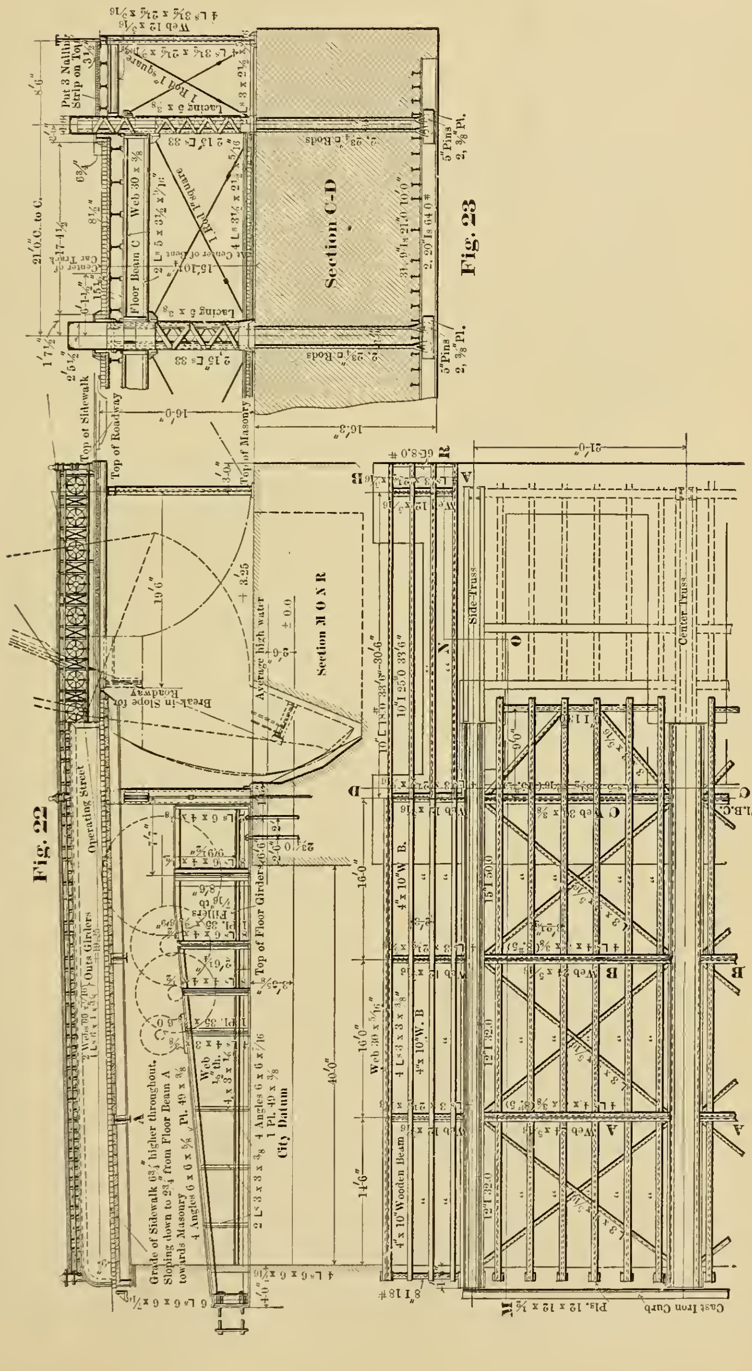


Fig. 22

Fig. 23

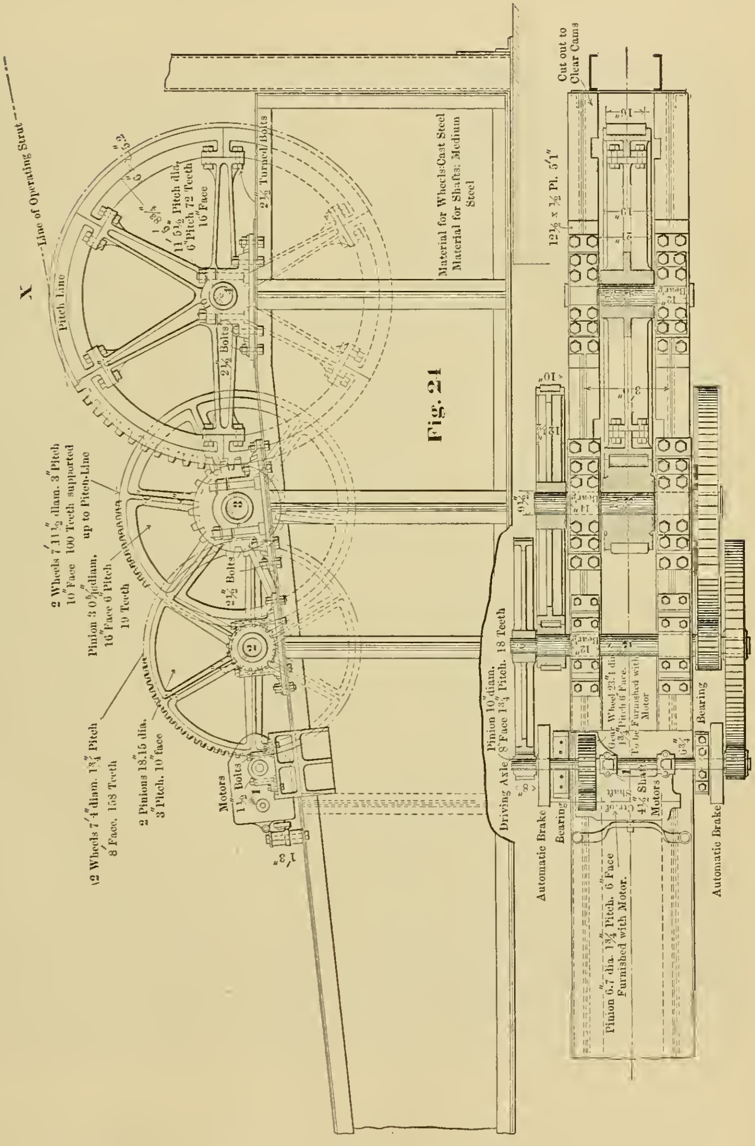
only is illustrated (Fig. 22). In the longitudinal section is shown the machinery girder, with the position of the motors and machinery indicated. This machinery girder is a very heavy box girder, 4 feet wide and $8\frac{1}{2}$ feet deep at the pier end. Besides carrying the vertical loads of the motors and machinery, it receives the longitudinal thrust brought to the machinery by the operating strut. To resist this thrust, the girder is anchored at the west end by four $1\frac{3}{4}$-inch rods passing entirely through the abutment, and at the east end by four $2\frac{3}{4}$-inch rods reaching to the bottom of the pier.

In the half cross-section through the approach (Fig. 23), is shown the anchorage for the approach girders, which act as anchors for the river span. This anchorage was placed directly upon the grillage foundation of the pier.

MOTORS AND MACHINERY.

In Fig. 24 is given a plan and elevation of the machinery for one-half the draw. The power being applied by the motors to shaft No. 1, is passed through the train of wheels to the operating strut at *X*. Of this machinery, all the gear-wheels are of cast steel, excepting the arms and hub of the rack-wheel. In this latter wheel, the power is applied on the rim and carried by the rim to the operating strut, for which reason the center was made of cast iron. The rim was cast in one piece, and not in sections as shown. Each of the other gears was cast in a single piece. The large wheels on shaft No. 2 were made with eight arms instead of six, as shown. On the middle of shaft No. 2 a brake-wheel was added, which is not here shown. This wheel is 5 feet in diameter, and has an 18-inch face. An 18-inch steel band brake is operated on it by compressed air. This brake is intended to be used only in case of an accident to the other brakes. The automatic brakes shown on shaft No. 1 were placed outside of the gears to make room for the motors, which are both on one shaft. These changes and some further additions are clearly shown in Fig. 25, which is produced from a photograph, taken after the work was completed.

The original specification for all cast steel was as follows: Ultimate strength of at least 70,000 pounds per square inch; elastic limit at least 40,000 pounds per square inch; an elongation, in 8 inches, of at least 25 per cent., and a reduction at point of fracture of at least 40 per cent. All sample bars, from which test specimens are made, to be at least $2\frac{1}{2}$ inches square, and to be annealed with the castings which they represent. So much difficulty was experienced in obtaining steel of this quality in *any* of the large castings required, that the specification was changed to the following: Ultimate strength of not less than 65,000 pounds per square inch, and elastic limit of at least 32,000 pounds;



Line of Operating Strut
X
Pitch Line
11' 5½" Pitch dia. 6" Pitch 72 Teeth 16" Face
2½" Turned Bolts
Material for Wheels: Cast Steel
Material for Shafts: Medium Steel
2½" Bolts
2 Wheels 7' 11½" diam. 3" Pitch 10" Face 100 Teeth supported up to Pitch-Line
Pinion 3' 0⅝" diam. 16" Face 6" Pitch 19 Teeth
2 Wheels 7' 4" diam. 1¾" Pitch 8" Face. 158 Teeth
2 Pinions 18.15" dia. 3" Pitch. 10" face
Motors
1½" Bolts
Pinion 10" diam. 8" Face 1¾" Pitch. 18 Teeth
Driving Axle
Automatic Brake
Bearing
Cut out to Clear Cams
12½ x ½ Pl. 5' 1"
Pinion 6.7" dia. 1¾" Pitch. 6" Face Furnished with Motor.
Automatic Brake

Fig. 24

elongation, in 8 inches, at least 20 per cent., and reduction at point of fracture of at least 25 per cent. This specification was filled only after rejecting many of the larger castings once, and some even twice, and the rim of the rack-wheel was accepted with an elongation considerably below this specification.

There are two 50 horse-power railway type, series wound, Westinghouse motors for each half of the draw, which are governed by a series multiple controller and connected to operate separately or in unison.

The automatic brakes are 30 inches in diameter with a 6-inch face, and are operated by compressed air. If at any time during the opening or closing of the bridge, the current is cut off, these brakes are automatically applied, and remain on until released by the operator. The air for use on these brakes and for operating the gates and signals is compressed by a compressor operated by an eccentric placed on the end of the motor shaft. This arrangement makes the compressing of the air also automatic. A pressure of about 35 pounds is used, a valve on the pump releasing the air above a pressure of about 40 pounds, although the compressor continues to work while the motors are in operation. The air, for use on both sides of the river, is compressed on the west side; that to be used on the east side being piped across, beneath the river, and stored in a reservoir. With the exception of the air compressor the machinery on the east side is a duplicate of that shown for the west side.

The bridge is provided with two gates, of the ordinary railroad type, one of which is placed on the right-hand sidewalk of each approach. When closed, each gate stops the traffic on the right-hand roadway, thereby enabling the operator to quickly clear the bridge of traffic and make it ready for opening. When once open, the bridge itself forms a very effective gate both for the roadway and sidewalks. Each operator controls the gate on his side of the river. The signals, which are at the center of the span, are operated from the west side.

In addition to the electric equipment already mentioned, each operator's house is provided with an electric heater, an electric bell and push-button, by which, with a code of signals, the operators may communicate quickly, and also with a special telephone for use in case of any accident when the bridge is open, at which time it may be necessary to communicate some message not provided for in the code. Everything has been added to the bridge which was considered necessary to insure the safety and reliability of its operation.

The power for running the bridge is a 500 volt current brought from the Chicago Edison Company's Washington Street power station.

From quite a large number of tests made on the current at different times and with the wind from various directions, it has been found

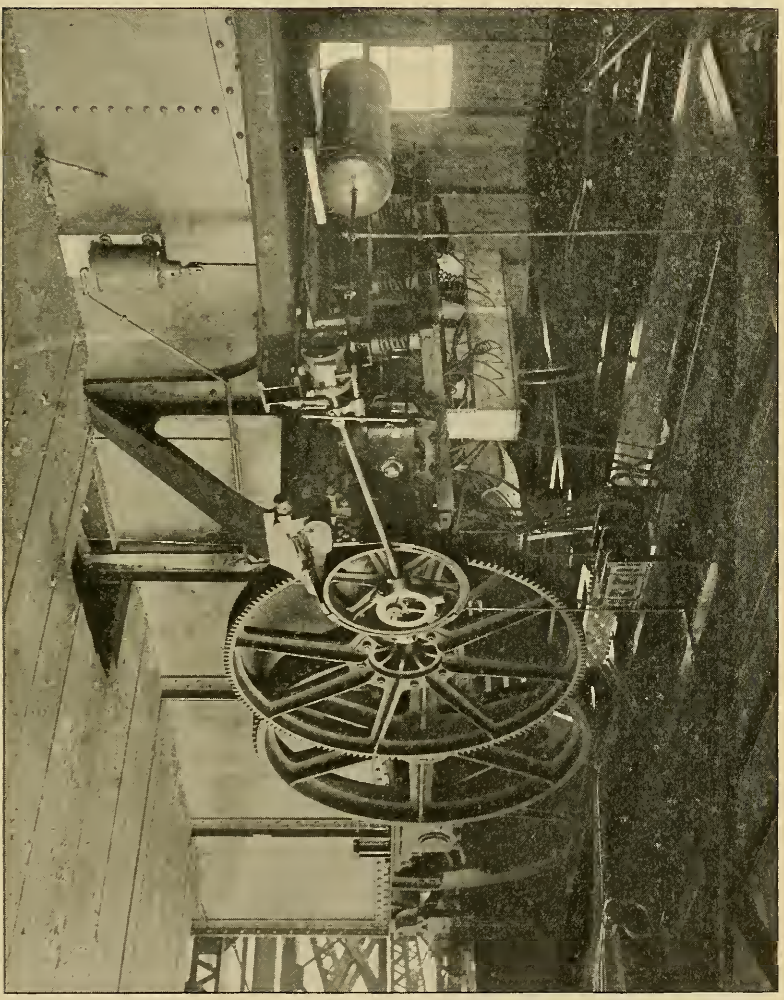


Fig. 25.

that the average horse-power required to open one side of the bridge at a time is about 60, and that required to open both sides at the same time about 96. However, none of the tests were made at a time when the wind was higher than what would be termed brisk. It was observed that a moderate, or even brisk wind, blowing from one side, offered more resistance to the operation of the bridge than one of the same velocity blowing in the direction of the street. This was due, no doubt, to friction that a side wind caused between the racks on the segmental girders and those on the masonry. It is not believed that this resistance from a side wind would exceed that from a direct wind of the same velocity for winds higher than those observed.

CONSTRUCTION AND COST.

The bridge was designed and patented by the late William Scherzer, who died about the time the drawings were completed. That the work performed by him had been *very* carefully and thoughtfully done is shown by the closeness with which his design has been followed by those who have carried his work to a successful completion.

Work was begun on the substructure early in 1894, and the bridge was completed and opened for traffic on February 4, 1895. Since this date it has been operated very satisfactorily. The time required for opening it is about one-half that for opening a steam-power swing bridge.

In comparison with a swing bridge, giving the same clear channel, the cost of this bridge seems somewhat high. This may be partly accounted for by the fact that this bridge is of a new design. Contractors do not bid so reasonably on such a design as on work with which they are familiar. Neither can the work be done for the same unit price on a bridge of new design as one of a familiar design. Moreover, the substructure of this bridge was more expensive than it would ordinarily be, even for a bridge of the same type. This was due to the difficulty in putting in some of the foundations.

The total cost of the bridge, including the approaches, electric equipment and cables to the power house, was $163,850.00.

The substructure for the bridge was built by the Fitz Simons & Connell Co., of this city. The contract was awarded them at unit prices for each kind of material entering into the work, and not for a lump sum. This method added very much to the responsibility and work of the engineers in charge for the city. Mr. W. R. Kellogg, a member of this society, had charge of the field work on the bridge, throughout its construction. Much of the credit for the manner in which the parts of the superstructure came together, is due to the accuracy with which Mr. Kellogg located the substructure. Some parts of the substructure, as

already shown by the illustrations, were of an especially difficult construction, and much credit is due to the contractors for this work, for the manner in which it was performed.

The contract for the superstructure was originally awarded to A. Gottlieb & Co., but Mr. Gottlieb's death soon afterward made it necessary to re-let the work, and it was given to Charles L. Strobel, a member of our society. Mr. Strobel sub-let the manufacturing of the iron work to the Elmira Bridge Co., of Elmira, N. Y., and the manufacturing of the machinery to the Scaife Foundry & Machine Co., of Pittsburg. Mr. Strobel and his able assistants, who made the shop plans for the bridge, deserve much credit for the care with which all the details of the bridge were worked out.

The electric equipment and air plant, including the brakes, air compressors, gates, signals, etc., were designed and furnished by G. P. Nichols & Bro., of Chicago. The former is also one of our members.

The bridge was constructed under the supervision of Mr. Samuel G. Artingstall, City Engineer, the author of this paper having direct charge of the work.

The following figures on the cost of this bridge as compared with certain other city drawbridges may be of interest:

Wells St. Swing Bridge:

Substructure	$59,000 00
Superstructure	86,700 00
Machinery and engines . . .	4,700 00
	$150,400 00

This bridge has two roadways of 21 feet each center to center trusses and two sidewalks of 8 feet each, is 220 feet long, and gives two clear channels of about 72 feet each.

South Halsted St. Lift Bridge:

Substructure	$84,700 00
Superstructure	81,400 00
Machinery and engines . . .	50,000 00
	$216,100 00

This bridge has one roadway of 40 feet center to center trusses and two sidewalks of 9 feet 4 inches each. It is 130 feet long center to center bearings and gives one clear channel of 118 feet.

Van Buren St. Rolling Lift Bridge:

Substructure	$79,600 00
Superstructure	73,100 00
Electric equipment	11,150 00
	$163,850 00

This bridge has two roadways of 21 feet each center to center trusses and two sidewalks of 8 feet 6 inches each. The channel span is 115 feet long center to center bearings, and gives a clear channel 109 feet (between masonry abutments).

N. B.—The engineering and inspection expenses are not included in any of the above costs.

DISCUSSION.

A VIEW of the Tower Bridge in London, England, taken at the time of its inauguration and presented to the society by Mr. Liljencrantz was then shown and Mr. Strobel furnished the following data:

The first caisson was begun in September, 1886. Both piers were completed in January, 1889. The formal opening of the bridge took place June 30, 1894. The steel work was furnished by Sir William Arrol & Co.; the contract price was $1,685,000. The piers and abutments, John Jackson's contract, cost $656,000. The hydraulic machinery, Armstrong & Co.'s contract, cost $426,000. The masonry superstructure cost $745,000. Other contracts, $636,000, making a total of all original contracts, not including outside expenses, nor engineering, of $4,150,000. The opening span is 200 feet, which is twice the opening in Van Buren Street bridge. The weight of each leaf is about 1,000 tons gross; the pressure in the accumulators is 850 pounds per square inch. The test load of 150 tons on the end of each leaf gave a deflection of $1\frac{5}{8}$ inches.

THE PRESIDENT:—The account of the tower bridge is certainly very interesting; in fact, the explanation of its cost of over $4,000,000 as compared with $160,000, seemed desirable, as the architectural effect is rather elaborate.

MR. BUSH:—I will say that Mr. W. W. Curtis, who represents the Pittsburg Bridge Company in this city, had expected to take part in this discussion to-night, but as he was unable to be present, has asked me to read for him a few notes prepared by him.

The following paper was then read by Mr. Bush:

MR. CURTIS:—Mr. Roberts has very kindly given me an opportunity to look over his paper, and present such discussion as I might desire, especially with reference to the comparative merits of the Van Buren Street bridge and the Halsted Street bridge, with which I was directly connected.

The society is indebted to Mr. Roberts for the very complete manner in which he has described this piece of work. This city seems to be especially selected as a trying ground for new schemes in the way of

bridge construction. Draw spans have been worked out here to somewhere near the limit of perfection so far as their efficiency in the line of public service is concerned, and unquestionably the same care and freedom in expenditure in first cost will insure a corresponding development in whatever type of bridge may be found best suited to the local conditions. Of the three different types of bridges built since it was found necessary to substitute something for drawbridges, one represented the extremely cheap, the second the extremely costly, while the third is somewhere near the golden mean, so far as cost alone is concerned. Fortunately the city in its experimenting has not been called upon to pay the cost of any absolute failure, all of their bridges being successes to a greater or less degree.

In comparing the Halsted Street and the Van Buren Street bridges there are several points which should be borne in mind to do justice to the former. It was a much more radical departure from existing structures than the Van Buren Street bridge, and the conditions under which it was built were very different. Plans for the latter work had been made by Mr. Scherzer and very cordially adopted by the Engineering Department of the city. The contracts called simply for the proper execution of the work according to the plans and specifications of the City Engineer, and the contractor was responsible in no way for the design or the successful operation of the structure, excepting in so far as that might be affected by poor work on his part. On the other hand the Halsted Street bridge was never looked upon with any favor by the city; its failure was predicted time and again, and while I very willingly recognize the fact that the City Engineer and his assistants endeavored to treat the contractors with perfect fairness regardless of their opinions of the wisdom of the expenditure of money entailed by the contract, the contractor was nevertheless compelled to assume risks on the enterprise to an unreasonable degree, and there was not the same interest taken in the bridge as in the Van Buren Street structure. The contractor was compelled not only to give the usual bond, guaranteeing the proper execution of his contract, but was also required to file a special bond for $50,000, guaranteeing the correctness and the sufficiency of the engineer's plans for the entire structure, the $50,000 to be forfeited in case the bridge was not made a perfect success. It seems now of course that such a bond was a mere formality, but at the time this work was constructed there were several questions which could not be determined in any way except by actual tests, and which, if such tests had not resulted favorably, would have caused a more or less complete failure of the whole enterprise, or would have entailed very heavy additional expense to have insured its success. Under these circumstances it is not surprising the cost figured for the machinery was large; or that in

the actual construction a large amount of money was spent in precautionary measures, which we now see could have been saved.

Examining the statement of the cost of the Halsted Street bridge as given by Mr. Roberts, we find it divided as follows:

Substructure	$84,700 00
Superstructure	81,400 00
Machinery and engines . . .	50,000 00
Or a total of . . .	$216,100 00

Of the item of substructure, $34,000 alone was required for the pneumatic caissons, the balance covering the cost of removing the old pile work in the river, a large amount of dredging, the masonry in the four main piers and two small piers, together with the retaining walls and engine-room foundation, with the various piles and timber required therefor. The item of engines and machinery covers a complete steam plant in duplicate, consisting of two boilers and two engines, with the necessary gearing and shafting, besides the counterweights, cables and their necessary connections and supports. In the construction of a similar bridge the expensive engine room beneath the street, as well as the steam plant, would be eliminated entirely, resulting in a considerable saving in first cost as well as a very large saving in cost of operation, which is now the worst feature of the Halsted Street bridge. By placing the power house in one of the towers above the roadway and using electric power furnished from a central station, the number of attendants required as well as the cost of power would be no greater in the case of a lift bridge than for the Van Buren Street bridge. It may be said that the two pieces of work should be compared as they stand, not as they may be modified in the future designs; but this is hardly a fair way of looking at it, because of the much greater novelty of the Halsted Street design, and the fact that the power was generated on the work itself instead of being purchased as at Van Buren Street, thus adding to the first cost of the power plant. There is another item also to be considered, viz.: the difference in the cost of material at the time the two pieces of work were contracted for. By referring to my estimate book I find the difference in the market price of angles amounted to $13.00 per ton, which, on the weight of the Halsted Street bridge, represents about $9,500.00. Mr. Waddell, the designer of this bridge, has placed himself on record in the *Transactions of the American Society*, as believing this bridge could be duplicated, with such modifications as I have suggested above, for $50,000 less than it actually cost. While I think the gentleman is possibly a little too sanguine in this, I am confident $175,000 at the present time would be sufficient to cover the expense of such a construction.

The main objection raised by engineers to a bridge of the type of the Halstead Street bridge, has been based upon the apparent absurdity of moving such a heavy mass to the height necessary in order to open the channel. On the face of it, it certainly seems that there should be some method requiring a less expenditure of energy to secure this result, and it is interesting to compare the actual power required in the two structures under consideration. Tests made at Halsted Street for Mr. Artingstall by Mr. Frederick Sargent, indicate that with both engines working at a high speed and opening the bridge in the shortest possible time, 115 indicated horse-power was required, while operating as in actual practice, with one engine alone, and at a speed 20 per cent. less, the power developed was 96 indicated horse-power. The power furnished for this work consists of two engines of a nominal rating of 60 horse-power each, with steam at 80 pounds pressure. Mr. Roberts states the indicated horse-power required for the Van Buren Street bridge, to be 96 horse-power, which may be reduced possibly by more accurate counterbalancing. He states, there are two 50 horse-power motors supplied for each half of the draw, or 200 horse-power supplied for the bridge, as against 120 horsé-power at Halsted Street. You will also notice the clear opening in the Van Buren bridge is 10 per cent. less than at Halsted Street. The speed for opening the two structures apparently is not very different, either being sufficiently rapid for any conditions.

The only doubt I have ever entertained as to the value of the rolling bascule bridge has been based upon the possible effect of a collision. This was one objection raised to Halsted Street bridge, but that structure has passed through three collisions with credit to itself and injury to the boat. What the result would be if it were struck by the bow of one of the heavy lake steamers there may possibly be room for doubt, but I believe the probability of serious injury from collisions is exceedingly small. With the bascule bridge of whatever type, I think such a collision as one already experienced at the other bridge would result in the demoralization of the bridge and its being thrown out of service for some days at least; and such collisions are extremely probable. It is to be hoped experience will prove the Van Buren Street bridge has greater resisting power as against such accidents than the writer believes it possesses. I lelieve the direct lift bridges have a province of their own and that therein they are superior to any other structure, and I shall certainly rejoice if Mr. Scherzer's last work remains as successful as it is to-day.

Mr. Goldmark.—Mr. Roberts, in this very interesting and excellent paper, has given perhaps the fullest account of any of the newer bridges that we have in Chicago. The drawbridges, as he very truly remarked, have reached a high state of perfection. They are certainly efficient, but there are many reasons why the drawbridge is not well

adapted to a narrow river of this kind, where the value of real estate and of dock room is extremely great. The Van Buren Street bridge— I think everybody who saw it operate the other day will agree—seems to be an extremely satisfactory and efficient machine or tool for doing the particular work which it has to do, that is, to carry a heavy roadway traffic at a moderate height above the river, and at the same time give a clear opening of 100 feet for vessels. The height above the river there is limited, and consequently there is considerable difficulty in finding room for the counterweights, as it moves downward. In fact, even in Van Buren Street there are large excavations in the concrete, and a possible influx of water will have to be taken care of, and still the Van Buren Street and our other Chicago bridges down town are not extremely close to the water. There is considerable height, I think twenty-four feet, from water to roadway. In many cases, in Chicago and in other cities, this distance from roadway to water is much less, and a bridge which is counterweighted by a tail end in that way presents certain difficulties.

Another thing in connection with this bridge that strikes me is that the 100 feet clearance, which is provided here, is probably somewhere near the limit to which a bridge of this kind can be economically built. I think that whatever may be said of the direct lift bridge, such as is used at Halsted Street, it certainly can be used for considerably greater lengths. For lengths of 200 feet it would find a more useful field for application than it did find here, because the difficulties of building such a bridge would probably not increase so much as in the case of a cantilever, in which the deflections increase very rapidly with the space overhung.

Mr. Curtis has given a very interesting explanation of the Halsted Street bridge, and I really got up to say a word or two about the other bridge that Mr. Curtis referred to, which was the cheap bridge of the three novel types. Some three years ago, when I entered tho employ of Messrs. Shailer & Schniglau, they had taken the contract for the Canal Street bridge for a total contract price for superstructure, substructure and machinery, including the iron approaches, of $40,000. This bridge was to have a clear span of 80 feet, and the approaches made the total length, if I remember rightly, in the neighborhood of 175 feet. The roadway was to be 20 feet wide, with two sidewalks, 5½ or 6 feet each. The iron work of the approaches had been designed in two separate short spans on each side. They were afterwards changed to single plate girders. The general outline of the bridge had been detailed by Mr. Kandeler sufficiently to make his bid and estimate. The bridge was taken up in the office and worked out with some care, and I want to say that I know from experience that any bridge of this kind

involves an infinite amount of patience and of work in order to make it go together at all, and I realize that the gentlemen who have had to do with the Van Buren Street bridge must have had a great deal of patience and a great deal of skill to get such a perfect structure.

For the Canal Street bridge I will say that, although it was designed for a rolling load of 100 pounds to the square foot, the strains in no part of the structure are at all heavy. The bridge fulfills its purpose perfectly, and carries the heavy teaming traffic of the lumber district with safety and without any excess of deflection where the two ends meet, though they are not locked in any way. The substructure was built somewhat in the way the Van Buren Street bridge was, that is, it consists of piles cut off 16 feet below low water, with concrete and stone piers above, the four small piers being independent, and the abutments being built in a similar way. The machinery is independent, and includes two double cylinder engines in each of the little houses on each approach, with a place for coal. In comparison with other bridges, I think the contract price is perhaps quite an interesting item. For more money we could, of course, have built a heavier bridge, and perhaps a more ornamental bridge, but I think that the Harmon patent on which this bridge was built is really a very economical style. There is no place in which the strains, either in tension or compression, are large. All the girders or beams are reduced to small sizes, and the load is carried very directly to the towers and to the piers, and when there is a cantilever action, it is taken care of by a tower about 40 feet high. Of course that is a very economical way of taking care of a cantilever, rather than by the comparatively shallow girders such as are used at Van Buren Street. It does not look as well, I admit, but it is certainly more economical, and I think it explains in a considerable measure the difference in cost between these two bridges.

Mr. Hasbrouk.—I would ask for what reason the Van Buren Street bridge was made of two independent cantilevers, rather than an arch, as the Metropolitan is.

Mr. Strobel.—I would say that in case of the Van Buren Street bridge, there is no particular advantage to be gained from treating the bridge as an arch. In the case of a longer span I should consider there would be an advantage in arranging to have the two parts meet in the center and act as an arch. The thrust on an abutment of a Chicago river bridge is never a desirable feature, as the soil is very yielding.

Furthermore, there is a wedge action which might take place if the bridge acted as an arch, which would make the opening of the structure harder and would require more power.

I may add, as it may not have been explained as fully in the paper as might be, that this bridge could have been balanced perfectly. The center of gravity could have been arranged to coincide with the center of the segmental girders. In that case the balance would have been complete in every position of the bridge. It was preferred, however, to arrange the balance so that there would be a tendency for the bridge to open as soon as it was unlocked. Then, in lowering the bridge, the position of the center of gravity is such that the bridge will drop a part of the way. After it has reached pretty nearly a horizontal position, the bridge has to be forced down to a complete horizontal position.

Mr. Hasbrouk.—The question raised in my mind was in regard to the deflection—whether or no it is wise, or otherwise, to make two cantilevers. We have two cantilevers, it strikes me, that having one arm loaded, the deflection of that arm might be considerable, and the other arm not being loaded might make a break in the bridge at the center.

Mr. Roberts.—For the loads that we have here in the city there is no deflection. As yet, we have had nothing heavier than a six horse team with a very heavy load go over the bridge. I was on the bridge the other day when a six-horse team crossed it, and there was no such deflection. The castings at the center through which the 3-inch steel pins work are very heavy; and, I think, are entirely capable of taking up even greater loads than we will have on this bridge. How it would be on a railway bridge, as the Metropolitan, where they have a heavy motor-car, I cannot say.

Replying to the question that was suggested by Mr. Goldmark, he thinks that we have very nearly reached the limit of span for which this type of bridge is adapted. I would say that I think not, so long as we can have a little more head-room. We only have about 15 feet from the bottom of the track to the center of motion. Where the approaches could be made longer and the bridge made higher, there is no reason why the span could not be made materially longer.

Mr. Bush.—Assuming a pressure of 18 pounds per square foot strikes me as being considerably lighter than ordinary specifications.

The President.—Mr. Roberts is called upon for too much in the way of explanation, and hence I will presume to answer Mr. Bush with the suggestion, that with a pressure of 18 pounds per square foot from wind it is quite safe to assume that there will be no navigation on the river, hence no occasion to expose the draw.

Mr. Appleton.—The description of this novel structure is certainly very interesting. There are a few points about the operating machinery on which I would like a little more information. As I

understand it, the brakes on the small wheel, as well as on the large wheel, are operated by compressed air, and that there is but one air pump. It would seem desirable to have some form of hand brake for use in case of failure of the compressed air through leakage or breakage of pipes.

This bridge is operated by electric motors. The current comes from a distant station operated by a private corporation. If the current should fail at any time, what would become of the bridge? Would it not be well to have a duplicate line of cables to supply the electric current? And would it not be well to have some kind of hand gear for use in emergencies? And, asking for information merely, what are the advantages of electric motors in this case over steam engines?

The President.—Mr. Roberts has been called on so often to answer questions. I think I will call on Mr. Nichols.

Mr. Nichols.—As I was acting in the capacity of contractor, placing the motors there was a matter of course. There certainly are advantages in the use of electric motors. The combined capacity of the two motors is 150 horse-power. You can imagine how much room a steam plant that will generate that amount of power would take up, with all the boilers and the stack and everything pertaining thereto. It would necessarily be duplicated on the other side, which would be practically an impossibility, although I suppose it might be done some way.

As to the comparative cost of operation by steam and electricity, that is purely a matter of arrangement between the city and the parties furnishing the current. It is true that in the transmission of power by electricity there is a loss of about 25 per cent. between the generating point and the point of application, but that is more than offset by the fact that so much less space is required.

As far as the danger of the current failing is concerned, it is hard to conceive of a more perfect or more reliable system. With such an engine and steam plant as is usually placed on a bridge, the conditions are necessarily unfavorable for efficient service. The source of power, or generating plant, is at the Chicago Edison Company's station, at the corner of Market and Washington Streets, where they have compound engines of large units and in duplicate, and the same with the boilers and generators, so that if anything should happen to any part of the plant, a duplicate part could be substituted. The building is practically fireproof. Connection is made between the generators at the station and the motors on the bridge by heavy armored cables laid in iron conduits under ground. The diameter of the wire conductors is something like $\frac{3}{8}$ inch, and, with the insulation, is something over an inch, so it would be very hard to rupture the circuit by mechanical means. As far as

burning out is concerned, that is hardly possible, as the type of motor used is such as designed for street car and electric locomotive work, and is designed with reference to rough usage, excessive overloads and scarcely any attention; so, comparing electricity with steam, the advantages are greatly in favor of the motor. For comparison we can refer to the bridges that have previously been equipped with motors. At the Rush Street bridge there was less trouble than with the new Madison Street bridge, which was started about the same time. There were several stoppages with the steam bridge, while with the electric, none at all. Similar results were obtained in Milwaukee. At the time the Grand Avenue bridge was equipped with an electric motor, the Michigan Street bridge was equipped with steam. The City Engineer has no hesitation in saying there is no comparison between the operation of the two; the steam bridge caused them some trouble, the electric none.

Why no provision was made for hand power is for Mr. Roberts to say, as that question did not come within the province of my work. While the air brakes have in every respect come up to our expectations and have proved themselves to be extremely reliable and easy of operation, and have not in a single case failed to act quickly and positively, it has been decided by the Bridge Engineer that it would be wise to provide supplementary brakes to be worked by hand, in case of emergency.

Mr. Johnston.—In regard to the remark that was made about the advantages of having one clear span, rather than two more narrow ones, ease of navigation has been claimed for the former. The question to be considered, in the Chicago River, is one of flowing water with only the draw span through which to flow. It occurs to me that perhaps a swing bridge, with two 55-feet openings, as at Madison Street, on the map herewith, would offer more easy navigation than one with 110-feet single opening, as at Van Buren Street. With running water in the river, as will be the case in the future, a mean velocity of 3 feet per second may be fairly expected through the openings, the depth being taken at 16 feet. The cross-section of many boats that will navigate the stream, will be nearly one-half that of the stream through the draw-opening. The effect will be to double the velocity as the boat passes the bridge, or to give a velocity of six feet per second, which increased velocity will oppose quite a resistance to the motion of the boat. In the case of the swing bridge with two clear openings, when the boat has entered one of the openings, nearly all the flow will be forced through the other. The velocity of flow adjacent to the sides of the boat will thereby be diminished, as will also the resistance to motion. I think it is very doubtful whether in this case, where the cross-section of the boat occupies so large a proportion of the cross-section of the stream, there is any advantange in the clear opening over the double.

Again, in the case of boats passing each other. In the case of the double opening, we have in the main Chicago River, or as at the Madison Street bridge, what may be called a double-track passage. Two boats passing each other, each nearly 55 feet wide, in a span of 110 feet, would occupy nearly all the cross-section, and, as one boat passed the other, there would be set up cross-currents which would interfere quite a good deal with the handling of the boats. In the double opening, there is no such thing.

A map, showing the bridge-crossings from Madison Street to Harrison Street, would afford quite a study in this connection. A few more bridges in this region, and there will not be much left of the river. Too long a stretch of single track navigation is being created.

Mr. Liljencrantz.—I think I would agree with Mr. Johnston if the question concerned the way of constructing a bridge in a "straight" channel, but the Chicago River is unfortunately very far from a straight channel, and that is probably one of the main facts that brought about the devices of these three last new kinds of bridges, because in the short bends, in which several bridges are located, the one side (when a swing bridge is used) is frequently impassable by a boat of an average size, and therefore I think that in all such localities the center channel is far preferable. (And as the question of navigation has been taken up, I should like to ask—perhaps more in the interest of navigators than the engineers—inasmuch as Mr. Roberts mentioned, as I understood it, that the "clear channel" at Van Buren Street bridge was 100 feet, I should like to ask if that does not mean the width between the stone abutments, because the clear channel between the protections I have found to be only about 80 feet.)

The President.—Somewhat more than twenty years ago, in conversation with parties as to drawbridges for the Chicago River, I was assured it was a matter of a very short time, two to four years at most, till the traffic in the river would be done with lighters, the larger craft staying in the outside harbor, or going to the Calumet, and all the bridges would be of the fixed type. The prospect of any such change in the navigation interests or the bridges seems more remote than it did twenty years ago. In fact there is not at this time even a suggestion of the probability of any such change; hence it is fair to assume that we are to see much development, with many examples in the way of drawbridges other than the pivot kind so long the standard on the Chicago River.

ASSOCIATION OF ENGINEERING SOCIETIES.

VOL. XV. JULY, 1895. No. 1.

PROCEEDINGS.

Civil Engineers' Club of Cleveland.

CASE LIBRARY BUILDING, CLEVELAND, OHIO, July 9, 1895.—The meeting of the Civil Engineers Club of Cleveland was called to order at 8 P.M., by the President. Present, 22 members and visitors.

The minutes of the last meeting were approved.

Mr. Thompson, Chairman of the Committee on Resolutions upon the death of Mr. A. M. Wellington, reported as follows:

Resolved, That the Civil Engineers' Club of Cleveland learns with sorrow of the death of A. M. Wellington, one of its original members. He was among those who took great interest in its formation and was instrumental in placing it upon its present footing. He was its first representative upon the Board of Managers of the Association of Engineering Societies and was active in the affairs of the Association as well as in those of the Club.

In his death the profession of Civil Engineers sustains a great loss. And we shall miss his substantial contributions to its literature.

We desire to express our deep regret at his untimely decease and to convey to his family our sincere sympathy.

Resolved, That these resolutions be spread upon the minutes of the Club and a copy forwarded to his family.

The resolutions were unanimously adopted. President Mordecai spoke also in eulogy of Mr. Wellington.

The Executive Board reported the resignation of Prof. E. W. Morley, and the transfer from active to corresponding membership of Mr. F. S. Richards.

The Committee on Picnic, through Mr. Jno. L. Culley, reported progress.

Messrs. Palmer and Brown were appointed tellers to canvass ballots for Mr. R. Hoffman.

The Club then listened to the paper of the evening by Mr. Wm. H. Searles, "The Deflections and Stresses of a Flexible Ring Under Load." This description of his original investigations upon the subject was very interesting.

The President gave a short account of the late meeting of the American Society of Civil Engineers at Boston.

The Club voted to hold no meeting at the regular date in August. Mr. Robert Hoffman was announced elected to active membership, and at about 10 o'clock the meeting adjourned.

F. A. COBURN, *Secretary*.

THE LATE A. M. WELLINGTON.

REMARKS BY AUGUSTUS MORDECAI, PRESIDENT OF THE CLUB.

I, perhaps, was as well acquainted with Mr. Wellington as any one present As has been said of him, he was a man of remarkable energy. Blessed with a strong constitution, when any interesting problem really took hold of him he seemed never to tire, even working far into the night and forgetting to stop for his meals.

Born in Massachusetts in 1847, and graduated from the Boston Latin School, he became an articled student in the office of Mr. Henck, of Boston, the author of the well-known field book, and later connected with Mr. Frederick Lew Omstead in the Brooklyn Park Department, then with several railroad enterprises in the South, East and West as assistant engineer on construction. In 1878 he came to Cleveland as an assistant to Mr. Chas. Latimer on what was then the Atlantic and Great Western Railroad; after remaining in that position three years he went to Mexico as chief engineer of the Mexican National, and later became assistant general manager of that line. He returned to the United States in 1884 to become one of the editors of the *Railroad Gazette*, remaining with that influential journal three years, when he associated himself with Mr. Frost, of the *Engineering News*, and was one of its principal editors to the time of his death. During his connection with these journals he also acted as consulting engineer in many important works, making reports on the improvement of Toronto harbor; the abolition of grade crossings at Buffalo; the terminals of the Brooklyn bridge; the railroad system of Jamaica, etc.

He was always a student, and his energetic nature led him early to analyze and study the problems of railroad construction and maintenance. So impressed was he with these problems, and so desirous, as was natural for him, to give to others the benefit of his consideration of them that he early commenced publishing papers on railroad location. In 1874, when but twenty-seven years of age, he published the "Computation of Earthwork from Diagrams." From 1874 to 1878 he commenced his "Economic Theory of the Location of Railways," published as a series of papers in the *Railroad Gazette* and afterwards published in book-form. In 1887, the last edition, a much larger book on railway location, was published by him. He was an indefatigable compiler of facts and figures and a keen analyzer of what they showed. He was a ready and aggressive writer, and had a facility of expression which adds greatly to the value of his books.

My first acquaintance with Mr. Wellington was in 1878, when he was appointed assistant engineer on the Atlantic and Great Western Railroad. The organization at that time was different from what it is now on the New York, Pennsylvania and Ohio Railroads, and there were a number of young men in the office in Cleveland as Mr. Latimer's assistants. We soon came to value him for his real ability, zeal and energy, and for his invariable good humor and cheerfulness. The engineering department was then engaged in working out a number of interesting problems, among others the thorough organization of the department, making it more effective and giving it its true standing in the organization of the road. Among the engineering problems were those of lowering the grades; replacing the wooden bridges with iron ones; improving the permanent way by the adoption of standards for rail sections, frogs, switches, etc.; making complete maps of the line and securing full title to the right of way; work which all railroads, about that time, had to face. Under the admirable leadership of Mr. Latimer each of us had his special work, and Mr. Wellington rendered valuable assistance in many of these lines, more especially in the problems connected with the lowering of the grades, and in editing

the proceedings of the roadmasters' meetings, which Mr. Latimer inaugurated in order to bring more harmonious action and more effective work into his department. He was also busily engaged in carrying on a series of experiments looking to the determination of the axle friction of freight cars, and also, I remember, he reported for some of the technical journals the convention of the Society of Civil Engineers held in Cleveland, besides doing other literary work.

It was during this period that he married and commenced that loving companionship which lasted to the end. His wife was essentially a helpmate to him, accompanying him in all his wanderings, entering into all his plans, and living her life in his, a sacrifice which he certainly returned with a most perfect and true devotion. We do well to tender to her our sincere sympathy in her widowhood.

He was among the first to enter heartily into the idea of the formation of this Club, which owes much to his organizing ability and energy. He was the first, I think, to conceive of the idea of the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES. He was our first representative on the Board of Managers of that Association, and, in company with Mr. Benezette Williams and others, he helped largely in assuring its success. He was always interested in the welfare of the Club; and in later years, when I have met him in New York, he has often inquired as to its progress and as to the welfare of its older members.

There are in the profession men more scientific than Mr. Wellington; men more tactful than he; men who will leave monuments larger and greater than his, and yet his place will be found difficult to fill. His best work was, to my mind, the editorship of the *Engineering News*. He brought to that paper a facility of writing, an aggressive and forceful manner full of suggestion and vim, a good, clear understanding as to what a paper of that kind ought to be, and these were invaluable in raising its position and placing it where it now is in the list of technical papers.

In private intercourse he was a warm-hearted, conscientious man, faithful to his work, only wanting that work to be as well done as it could possibly be, not lowering others that he might rise, of even temperament, and although expressing his opinions forcibly, and retaining them with persistence, still carrying with it all a high sense of duty and a sincerity which won him the confidence of those who were fortunate enough to be intimately acquainted with him.

For his genius as a writer, for his ability as an engineer, for his love for his profession, and the purity and simplicity of his character, it is eminently fitting that we should pay a tribute to his memory.

His last illness was brought on by too close application in working out some problems in connection with a suggested change in the steam engine, putting in practical shape some ideas he had long entertained. Even his strong constitution could not stand the protracted want of exercise and of regular meals. We may exclaim with Byron:

> Oh what a noble heart was here undone,
> When science's self destroyed her favorite son.
> 'Twas thine own genius gave the final blow
> And helped to plant the wound that laid thee low.

Association of Engineers of Virginia.

ROANOKE, Va., July 11, 1895.—The regular summer meeting of the Association of Engineers of Virginia convened in Lexington on June 28, 1895, in the chapel of Washington and Lee University. The meeting was called to order by Prof. D. C.

Humphreys, who introduced Hon. William A. Glasgow, the Mayor of Lexington, who delivered an address of welcome, according to the Association the freedom of the town. This address was responded to by the Vice-President of the Association, Mr. M. E. Yeatman, and after the conclusion of his remarks he announced the meeting open for business.

On motion of Mr. H. A. Gillis, the business of the meeting was deferred until Friday morning.

Prof. Humphreys then gave a very interesting talk on the "Improvement of the Mississippi and Missouri Rivers," with which work he was connected for a number of years. He first explained the troubles due to the washing in times of flood and the changes that take place in the river bottoms, and with the help of lantern slides, made from pictures taken on the ground while the work was in progress, he explained the methods used in holding in check the washing and changing of position of channel.

Mr. Newall, of the United States Geological Survey, exhibited and explained to the Association the apparatus used for measurements of the current flow of rivers. This ingenious machine is arranged so that a screw turned by the force of water opens and shuts an electric circuit, which working a sounder registers the speed of the current.

Session then adjourned to meet Saturday, June 29th, at 9.30 A.M.

Saturday, June 29th, meeting called to order by Vice-President, M. E. Yeatman, at 9.30 A.M.

The following report by the committee appointed to recommend a standard gauge for sheet metal and wire was read and unanimously adopted :

To the President and Members :

Your committee appointed to draw up resolutions in regard to the introduction of the Decimal Gauge concludes that it cannot do better than to indorse the resolution adopted by the joint committees of the American Society of Mechanical Engineers and the American Railway Master Mechanics' Association, at their meeting in New York, February 13, 1895, which was as follows:

Resolved, That while the Micrometer Gauge should be used for test purposes in the laboratory, yet for general shop use a solid notched gauge is desirable. The form of this gauge should be an ellipse whose major axis 4 inches, the minor axis 2.5 inches, and the thickness .100 inches. There should be either one hole .750″ diameter in center, or one at each of the foci for lightening and convenience. This gauge must be plainly stamped with the words 'Decimal Gauge' in letters .200″ high, and below this the name of the trade which the group of notches is to cover, these groups to be selected with reference to the needs of the several trades.

All sizes of notches to be marked in thousandths of an inch without a zero prefixing the decimal point, but with inch marks after the figures, thus, .002.″

It is also the intention of this committee that in ordering material the term "Gauge" shall not be used, but merely the thickness in thousandths of an inch.

Your committee also recommends the following rules for the adoption by this Association as standard :

1st. The Micrometer Caliper should be used for laboratory and tool-room work, and in shops when specially desired.

2d. The solid notched gauge should be used for general shop purposes.

3d. The form of this gauge shall be an ellipse whose major axis is 4 inches, the minor axis 2.5 inches, and the thickness .1 inch, with a central hold .75 inch in diameter.

4th. For general railroad purposes the notches may be as follows:

.002″	.022″	.060″	.110″
.004″	.025″	.065″	.125″
.006″	.028″	.070″	.135″
.008″	.032″	.075″	.150″
.010″	.036″	.080″	.165″
.012″	.040″	.085″	.180″
.014″	.045″	.090″	.200″
.016″	.050″	.095″	.220″
.018″	.055″	.100″	.240″
.020″			.250″

5th. All notches to be marked as in the above list.

6th. The gauge must be plainly stamped with the words "Decimal Gauge" in letters .2″ high.

7th. In ordering material the term "Gauge" shall not be used, but the thickness ordered by writing the decimal as in above list. (For sizes over ¼″ the ordinary common fractions may be used.)

G. R. HENDERSON,
CHAS. S. CHURCHILL, *Committee.*
R. H. SOULE,

The report was unanimously adopted.

The following names having been duly approved by the membership committee were proposed for membership: Harry Frazier, Richmond, Va.; Wm. F. Wall, Price's Fork, Va.; Samuel M. Barton, Blacksburg, Va., and John T. Worthington, Roanoke, Va. On motion, the Secretary was instructed to cast the ballot of the Association for these members.

Mr. H. A. Gillis, of Roanoke, then read a paper on the "Surface Hardening of Cast Iron," exhibiting quite a number of specimens of cast iron hardened, with chill blocks of various thicknesses, and also of specimens of hardening by a process similar to that used in case hardening wrought iron. This paper brought out much interesting discussion, and on motion was referred to the publication committee.

Col. J. W. Brooks, of the Virginia Military Institute, exhibited the apparatus used by him forty years ago in making "deep sea soundings," and explained the methods and the results obtained. This device, as designed by Col. Brooks, is in principle the same as that now in use, though some improvements have been made in the matter of facilities for handling and by the substitution of steel wire for a hemp cord.

A vote was passed by the Association thanking the Washington and Lee University for the use of their buildings, the Town Council and citizens of Lexington for the hospitable reception given the Association, and the ladies present for their attendance upon the sessions of the Association.

Adjourned. JNO. A. PILCHER, *Secretary.*

Bradley & Poates, Engr's, N.Y.

Association of Engineering Societies.

Vol. XV. **AUGUST, 1895.** No. 2.

PROCEEDINGS.

Technical Society of the Pacific Coast.

Regular Meeting, August 2, 1895.—Called to order by President Dickie.

Minutes of the last regular meeting of June 7, 1895, approved. Jno. H. Hopps, Lincoln Nissley and Tom W. Ransom were upon ballot declared elected members of the Society.

The Committee on Resolutions relating to the removal of Prof. Geo. Davidson from the head of the Pacific Coast Division of the U. S. Coast and Geodetic Survey reported the following resolutions, which were, on motion, unanimously adopted, and the Secretary was instructed to send copies of the same to our Representatives in Congress and to furnish copies to the newspapers:

Resolved, by the Technical Society of the Pacific Coast: That the Society views with much concern an apparent tendency to curtail the work of purely Scientific Bureaus of the Government, or to transfer it to Departments where political and personal influence will be sure to impair the famous records of such Bureaus.

Resolved, That this Society, seeing additional evidence of this tendency in the removal of Prof. Geo. Davidson from the head of the Pacific Coast Division of the U. S. Coast and Geodetic Survey, expressed regret that he should have been removed without apparent cause, after a life service of the most brilliant character.

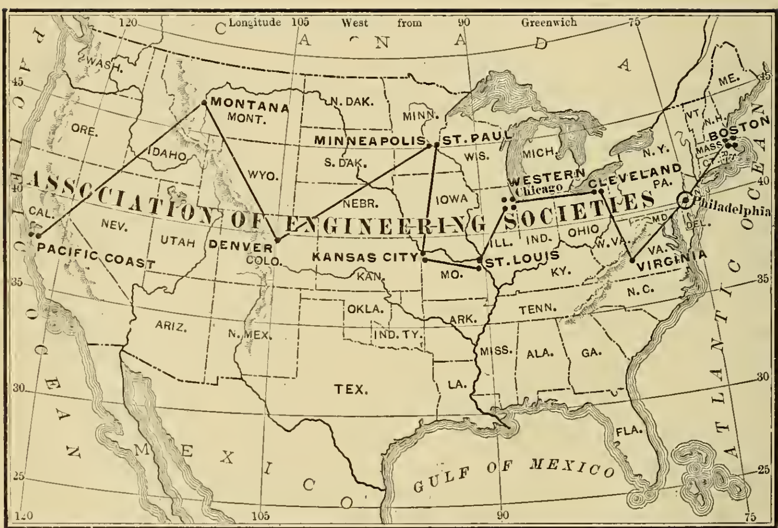
He has by years of efficient and distinguished service shown unusual devotion to scientific work, and his labors have been a credit not only to the Bureau with which he has been connected for nearly half a century, but they entitle him to the lasting gratitude of this Nation and particularly of the residents of this Coast, with whose interest he has so long been identified.

This Society further desires to express the hope that Prof. Davidson, in the vigor of his mature years, may yet find abundant opportunity for satisfactorily utilizing his professional and scientific attainments.

(Signed) John Richards,
Otto von Geldern, } *Committee.*
C. E. Grunsky.

Prof. Chas. D. Marx then read the paper of the evening: "Some Experiments on Water-ram in Pipes," which led to a discussion, in which President Dickie referred to the very interesting experience had on the "Comstock Lode" in connection with the ram in the pipes from deep shafts.

Adjourned. Otto von Geldern, *Secretary.*
Per C. E. Grunsky, *Acting Secretary.*



Bradley & Poates, Engr's, N.Y.

Association of Engineering Societies.

Vol. XV. SEPTEMBER, 1895. No. 3.

PROCEEDINGS.

Civil Engineers' Club of Cleveland.

Case Library Building, Cleveland, Ohio, September 10, 1895.—The meeting of the Club was called to order at about 8 o'clock, by President Mordecai. Present, 31 members and visitors.

The minutes of the last meeting were read and approved.

The reports of the Executive Board for their last four meetings were read and approved. The applications for active membership from Geo. S. Rider and F. A. Smythe were read.

The report of the Picnic Committee, Jos. Leon Gobielle, Chairman, was read, adopted and ordered placed on file.

Mr. Ambrose Swasey reported in regard to the excursion to Lorain. There were fifty-five engineers and visitors in attendance on that occasion.

The paper of the evening, entitled "Educational Architecture," was then read by Mr. Barnum.

Mr. Barnum spoke eloquently of the educative influence of architecture, the greatest of the fine arts; of the present status; the outlook, etc.

He was followed in discussion by Dr. Cady Staley, Architect John Eisenmann, and others.

Some views of the new Boston public library were exhibited at the request of President Mordecai, and that building was offered as an example of some good things that are now being done.

After the meeting, the Club adjourned to one of the vacant stores on the ground floor, and indulged in a light luncheon. F. A. Coburn, *Secretary.*

The Technical Society of the Pacific Coast.

Regular Meeting, September 6, 1895.—Called to order at 8.30 p.m., by President Dickie. The minutes of the last regular meeting were read and approved.

The following applications were read and referred to the Executive Committee, for members:

W. F. Englebright, Civil Engineer, of Nevada City, proposed by Hubert Vischer, Geo. F. Schild and Otto von Geldern.

Dana Harmon, Mining Engineer, of Nevada City, proposed by John W. Gray, Hubert Vischer and L. J. LeConte.

W. W. Waggoner, Mining Engineer, of Nevada City, proposed by C. E. Grunsky, Hubert Vischer and Adolph Lietz.

Mr. Edward S. Cobb then read the paper of the evening, explaining in detail the design of a large wrought-iron wheel. A discussion of the subject ensued.

The President then referred to the present condition of the Technical Society, and suggested the advisability of holding meetings of a social character, in order to bring together all the elements of the Society. Such meetings should be held at regular intervals, and might take the form of a dinner. After discussing the subject, it was moved that the Board of Directors make the necessary arrangements for a social gathering—or dinner—at the time of the next regular meeting in October, and that the Secretary be instructed to send the necessary circulars of information to the members, after the action of the Directors.

Adjourned. OTTO VON GELDERN, *Secretary.*

Engineers' Club of St. Louis.

421st Meeting, September 18, 1895.—President Russell called the Club to order at 8.30 P.M., at 1600 Lucas Place, fifteen members and two visitors present.

Mr. A. L. Johnson opened the discussion on "The Inspection of Structural Steel," the subject being of special interest just now on account of the widespread attention which has recently been given it in the columns of the *Engineering News.* Mr. Johnson stated the ordinarily accepted definitions of the terms "elastic limit," "yield point," and "break-down point." He showed the extreme difficulty of determining these characteristics, particularly with very high grade steel, such as is used in drawn wire. He doubted seriously whether any existing method gave us an exact determination of these points. He doubted furthermore, whether it was necessary to know them, as the ultimate strength and elongation told us all that was really essential for us to know about any material. In his opinion, advanced practice would warrant the omission of the elastic limit in all specifications.

Mr. Robt. Moore agreed fully with Mr. Johnson. The elastic limit being uncertain and difficult of determination, he had for some years omitted it entirely from his specifications.

Prof. J. B. Johnson called attention to the fact that for all commercial purposes the three points, elastic limit, yield point, or break-down point, were one and the same, and need only be considered separately in an abstract scientific study of the subject. He showed charts from tests recently made by Prof. Grey at Terre Haute, made on what is perhaps the best apparatus in existence for the purpose. These showed a practically straight line from the origin to the yield point.

Mr. Bryan thought that we should not lose sight of the elastic limit, for the reason that it and not the ultimate strength indicated what could be done with a material. It was important to know when the structure would begin to distort seriously, rather than when it would fail altogether. He thought it would be better to use reduced factors of safety, based upon the yield point rather than the ultimate strength. In reply, Mr. Moore stated that the ultimate strength and elongation were properties which could be readily and accurately determined, and that in all standard materials the elastic limit bore a certain relation to the ultimate strength, which relation did not vary materially.

President Russell called attention to the difficulty which the designing engineer met with in using the accepted formulæ when so much uncertainty existed as to the elastic limit.

William H. Bryan, *Secretary.*

Boston Society of Civil Engineers.

September 18, 1895.—A regular meeting was held at the Society rooms, 36 Bromfield Street, Boston, at 7.50 o'clock, p.m., President Albert F. Noyes in the chair. Sixty-seven members present.

The record of the last meeting was read and approved.

Mr. John F. Lyman was elected a member of the Society.

The report of the Committee on Weights and Measures submitted at the last meeting and referred to this meeting for action, was recommitted to the Committee for a full report.

The Secretary presented an engrossed copy of the resolution of thanks to this Society passed by the American Society of Civil Engineers at its annual convention in June last.

A communication was also read from Mr. O. Chanute, transmitting a photographic reproduction of a vote of thanks passed by the German Society of Engineers to the associated societies which maintained the engineering headquarters at Chicago during the World's Fair.

Mr. Howe gave notice in writing of a proposed amendment to By-law 1, changing the night of meeting from Wednesday to Friday.

The President announced the deaths of Willis H. Hall which occurred August 26, 1895, and Marshall M. Tidd, which occurred August 20, 1895, and by vote of the Society he was requested to appoint committees to prepare memoirs.

Mr. Percy N. Kenway read the paper of the evening entitled "A Study of the Heating and Ventilating Plants in the Suffolk County Court House and in the Massachusetts State House." The reading of the paper was followed by a discussion in which Prof. S. H. Woodbridge, who designed the State House plant, Mr. Frederic Tudor and others took part.

Adjourned. S. E. Tinkham, *Secretary.*

Adelbert L. Sprague.—A Memoir.

By Frank A. Foster and Frank O. Whitney, Committee of the Boston Society of Civil Engineers.

[Read June 12, 1895.]

Adelbert Leroy Sprague, son of William F. and Abbie J. Sprague, was born in Foxboro, Mass., October 23, 1872.

His parents removed to Boston in 1883, from which time he attended the Bigelow Grammar and English High Schools until his graduation from the latter in 1888.

He entered the City Surveyor's office, Boston, immediately after leaving school at the age of fifteen, being the youngest person ever employed in that department.

For five years he served the city with characteristic fidelity, rising from the position of rodman to that of an assistant surveyor.

In March, 1893, he gave up his position in the city service to take a more responsible one with the Brookline Gas Light Co., where he was engaged in work connected with the extension of their business into the city of Boston.

In June, 1894, he left the company's service and entered the office of Mr. Frank A. Foster; his work in that office was on the preliminary survey of the Middlesex Fells and Lynn Wood s Park Way, and later on the Blue Hills Park Way.

He was joined in marriage to Miss Mabel Lord, only three months before his death, which occurred April 12, 1895.

Although cut off at an early age he had gained for himself a reputation for carefulness and competency attained by few of maturer years.

His modest bearing, genial disposition and devotion to his profession endeared him to his friends and impressed all who knew him.

Association of Engineering Societies.

Vol. XV. | OCTOBER, 1895. | No. 4.

PROCEEDINGS.

Western Society of Engineers.

The Annual Pleasure Outing of the Society was an excursion to Milwaukee by the steamer "Indiana," Monday evening, August 5, 1895, arriving Tuesday morning. The attendance was not large, but the trip was a very enjoyable one. During the forenoon the party visited the new Sixteenth Street viaduct and Bascule Bridge, the shops of the Edward P. Allis Co., and the Chicago & Northwestern Railway drawbridge, operated by a gas engine. In the afternoon, carriages were taken for a drive about the city under escort of Mr. M. G. Schinke, Assistant City Engineer, visiting the new City Pumping Works, and Pabst's Brewery. Return to Chicago was by steamer "Virginia," on Tuesday evening.

A Special Meeting (332d) of the Society was held in the Society's rooms, Wednesday evening, August 7, 1895, for consideration of the action of the Board of Managers of the Association of Engineering Societies on the recommendations made to them by the Western Society of Engineers with reference to the conduct of the Journal, and also for the determination of the course the Western Society is to pursue with reference to the Journal. President Horton in the chair, and sixteen members present.

The objects for which the meeting was called were fully discussed by various members.

On motion of Mr. Robt. W. Hunt, it was voted "That the Board of Managers of the Associated Societies be requested to render the societies in the Association a financial statement for the first quarter of the present year, and for each quarter thereafter, showing the cost of the Journal, the number of members in each Society on the Journal mailing list, the amount of money paid by each Society, and the amount any Society is delinquent."

The following resolution was presented by Mr. J. J. Reynolds, and was duly seconded:

Resolved, That the Western Society of Engineers withdraw from the Association of Engineering Societies, and that the Secretary of this Society notify the Association of such action.

A letter ballot on the above resolution was demanded by five members: Messrs. J. J. Reynolds, Alex. E. Kastl, Ebin J. Ward, Frank P. Kellogg and B. E. Grant —under the provisions of Section 2, Article V of the Constitution, and the Presi-

dent announced that therefore a letter ballot would be taken on the resolution. Adjourned.

CHARLES J. RONEY, *Secretary.*

The invitation of the Chicago Ship Building Company, through its manager, Mr. W. I. Babcock, member of the Society, for the Western Society of Engineers to be present at the launching of the steel steamer "Zenith City," on Wednesday afternoon, August 14, 1895, was accepted by about 75 members and their friends.

For this enjoyable occasion and courtesies tendered, thanks are also due to the Shailer & Schniglau Co., the Fitz Simons-Connel Co., Messrs. O. B. Green and J. J. Reynolds, and to our efficient Excursion and Entertainment Committee, through whose joint efforts this junket was made without drawing on the Society's funds.

It is regretted that the time of notification to the Committee precluded sending invitations by mail to non-resident members.

THE 333D MEETING of the Society was held in the Society's rooms, Wednesday evening, September 4, 1895. President Horton in the chair, and thirty-five members present.

The minutes of the meeting of June 5th (331st), and of the Special Meeting of August 7th (332d), were read and approved.

The Secretary reported for the Board of Directors:

Applications for membership have been received and filed as follows:

As Members, James C. Long, U. S. Asst. Engineer, Tiskilwa, Ill., and John Cornelius Bley, Mechanical Engineer, Chicago.

At the meeting of the Board of Directors held July 2, 1895, the Treasurer reported a balance on hand, July 1, 1895, of $2,072.47.

Bills to the amount of $1,062.44 were approved and ordered paid. The above amount includes bills from the Association of Engineering Societies for the Final Assessment for 1894, and for the first and second quarterly assessments for 1895, amounting to $840.30.

Mr. Thos. T. Johnston was elected as Representative of the Society on the Board of Managers of the Association of Engineering Societies *vice* Mr. Thos. Appleton, resigned.

At the meeting held August 6, 1895, the Treasurer reported a balance on hand August 1, 1895, of $1,403.35.

Bills to the amount of $134.28 were approved and ordered paid.

The President announced the resignation of Mr. L. E. Cooley as a member, on the part of the Western Society of Engineers, in the Chicago Municipal Improvement League, and the appointment of Mr. Thos. T. Johnston to serve the remainder of the unexpired term.

The matter of letter ballot on the question of withdrawal from the Association of Engineering Societies was then discussed. The unanimous sense of the meeting was that the votes should be returnable on September 24th, and the result announced at an adjourned meeting at Armour Institute, on the evening of that day.

The Secretary announced the death of Mr. Wm. A. Hammett, a member of the Society, and requested information from members regarding Mr. Hammett's life and professional career.

The Secretary also read a letter from Mr. O. Chanute, accompanied by a translation of a letter from the Society of German Engineers, and a photograph

of an artistic memorial, expressing the thanks of the Society of German Engineers for the reception given its members by the Associated Engineering Societies at their headquarters in Chicago, during the summer of 1893, and the matter was, by vote, referred to the Board of Directors for suitable action.

The Secretary then read an invitation to the Society to appoint delegates to attend the First Annual Convention of the International Deep Waterways Association, to be held at Cleveland, Ohio, September 24, 25, 26, 1895, and the matter was referred to the Board of Directors with power to act. On motion, the meeting adjourned to meet at the Armour Institute of Technology, on Tuesday evening, September 24, 1895, at 8 P.M.

The adjourned (333d) meeting of the Society was held in Science Hall, Armour Institute of Technology, Tuesday evening, September 24, 1895. President Horton in the chair, and fifty-five members and guests present. The Secretary read the following report:

September 24, 1895.

The Western Society of Engineers:

We, the undersigned Judges of Election, appointed by the Board of Directors, having duly canvassed the vote cast on a special election, closing at 3 P.M., September 24, 1895, on the following resolution:

"*Resolved*, That the Western Society of Engineers withdraw from the Association of Engineering Societies, and that the Secretary of this Society notify the Association of such action," report as follows:

Total number of votes received	269
Rejected for informality	3
Total votes counted	266

of which 87 votes were No, and 179 votes were Yes.

Respectfully submitted,

WM. B. EWING,
JOHN W. ALVORD,
Judges of Election.

The President announced—The vote is in the affirmative, the ayes being in the majority, the resolution is carried, and the Secretary will give proper notification.

Mr. Ambrose V. Powell then read his paper, "Some Notes on the Dry Docks of the Great Lakes," illustrated by many fine lantern views, which were fully described as presented, and, after further interesting remarks by Mr. Powell, the meeting adjourned.

CHARLES J. RONEY, *Secretary.*

Engineers' Club of St. Louis.

422D MEETING, OCTOBER 2, 1895.—The President announced the death of Alex E. Abend, and stated that Mr. Edward Flad had consented to prepare a memorial for presentation at an early meeting.

On behalf of the committee, Mr. Robert Moore then presented to the Club the oil portrait of Colonel Henry Flad. His remarks were as follows:

Mr. President and Gentlemen:

Early in the present year several members of the Engineers' Club of St. Louis formed themselves into a committee to secure an oil portrait of Col. Henry Flad

for presentation to the Club. In the belief that many other members would esteem it a privilege to join in this undertaking, a circular letter was sent to every member, offering him the opportunity to contribute thereto. The response to this circular justified our expectations, and the requisite amount of money was easily secured. The committee thereupon engaged as artist, Mr. Chas. F. von Saltsza, of the St. Louis School of Fine Arts, who had executed some most admirable works of this character, and, what was no less important, secured also the co-operation of Col. Flad to assist the artist with sittings. The result is a portrait which a number of the intimate friends of the Colonel pronounce an excellent likeness, and which we think will commend itself as such to the Club at large.

To those who have had the privilege of a personal acquaintance with Colonel Flad, and the opportunity of knowing at first-hand his high personal and professional qualities, nothing need be said in justification of any steps to perpetuate his memory. To those who have not been thus fortunate, it will be enough barely to recall his honorable record as captain and then as colonel of a Missouri regiment of engineers during the late war; his service after the war as assistant to Mr. Kirkwood in designing the St. Louis water works, and then as a member of the Board of Water Commissioners, under whose direction these plans were carried out; his brilliant engineering work as a colleague with Captain Eads in the construction of the St. Louis bridge; his presidency of the American Society of Civil Engineers, and his twelve years' term as president of the Engineers' Club of St. Louis, of which he was a charter member; his fifteen years of service as president of the Board of Public Improvements of St. Louis, during which time the public works of the city were conducted with a fidelity and skill unsurpassed in any city of the world; and last, his present work as one of the most active members of the Mississippi River Commission. As soldier, as citizen, and as engineer, his career has always been marked by distinguished ability, unswerving integrity, and absolute devotion to the public good. No citizen is more worthy of perpetual remembrance in St. Louis than is Col. Henry Flad.

It is with no ordinary pleasure, therefore, that, on behalf of the committee and all those who have shared in this enterprise, I now present his portrait to the Engineers' Club of St. Louis, trusting that it may be long preserved as a reminder of his great public services, and as a continual source of pride and inspiration to the members of the Club.

Mr. Richard McCulloch then read a paper on "The Continuous Rail in Street Railway Service." He described briefly the work done in St. Louis and elsewhere, and the processes employed. The paper was illustrated by drawings, photographs, rail sections, and samples of joints. Two systems had been employed in St. Louis, electric welding and cast welding. The latter, requiring a less expensive plant, being simpler and easier to operate, and the work appearing to stand service better, had been given the preference. In spite of the extreme temperatures but a very small percentage of the joints had broken, and these were clearly due to defective welds. The cost was not greatly in excess of the old fish-plate method. It was thought that the rail being surrounded by earth or paving on all sides except the top, it was protected from the extreme variations of temperature and being held rigidly in position, these two features tended to counteract the expansion and contraction which would ordinarily be expected.

WILLIAM H. BRYAN, *Secretary.*

423D MEETING, OCTOBER 16, 1895.—President Russell called the Club to order at 1600 Lucas Place at 8.30 P.M. Twenty-two members and six visitors present.

Mr. Edward Flad read the following memorial:

"Alexander E. Abend was born at Belleville, Ill., in 1859. He received his education at Washington University, in this city, graduating from that institution in 1881 with the degree of C.E.

"For the first few years after leaving the university he devoted himself almost

entirely to railroad work, being employed as assistant engineer and division engineer on the Northern Pacific Railroad and the Oregon and California Railroad. Returning to Belleville in 1885, he was appointed to the position of constructing engineer and superintendent of the City Water Works of Belleville.

"Later he opened an office as Surveyor in East St. Louis, and in 1893 was appointed to the position of city engineer for that city.

"An era of improvement had begun in East St. Louis; large amounts of money were expended in grading and paving streets, constructing sewers and other public works. As city engineer such improvements were conducted under his supervision. The ability which he displayed in designing and carrying out this work is perhaps best attested by the fact that upon the election of the present mayor, some months ago, Alex. Abend was reappointed to the position of city engineer, although his sympathies were known to have been with the defeated candidate.

"Those of us who were his classmates at the university—and this Club numbers six such among its members—will remember Alex. Abend as a conscientious student, fair-minded, honest, possessed of good sound judgment, and a companionable disposition. He had those qualities which would lead one to predict a useful life, endeared with ties of love and friendship. And such was his life until an over-wrought nature succumbed to mental worry, and unable to longer bear up against the cares which beset him, he, with his own hands, put an end to the struggle on the afternoon of September 18, 1895.

"To his widow and family our deepest sympathy is extended."

Ordered that this memorial be spread upon the records of the Club.

President Russell then gave the Club the results of some tests on bronze for tension and compression, made by the Washington University testing laboratory for the water works extension. Tables of the results, with charts and diagrams, were shown. Messrs. Flad, Baier, A. L. and J. B. Johnson, Holman and Moore took part in the discussion. It was shown that the compressive strength of metals which flow could not be determined.

Mr. William H. Bryan then read a paper on "Pamphlet Filing," explaining the difficulties he had met with in filing and indexing the many kinds of pamphlets which an engineer receives, and giving his solution of the problem, showing how all the data on any one of more than a hundred different subjects could be immediately located.

Discussion followed by Messrs. Holman and Flad.

Mr. M. L. Holman then explained the break which occurred on Saturday, 12th inst., in the dividing wall between two reservoirs at the Chain of Rocks. The water had broken down through the concrete bottom of a full reservoir, and up into the adjoining empty reservoir. The concrete foundation had been entirely washed away, but the wall itself was intact, leaving a span of nearly 60, and a depth of 15 feet. It was proposed to repair it by concrete foundation under the wall, and puddling work under the concrete bottom.

Attention was called to the necessity of making provision for expansion and contraction of long masonry walls when built as monoliths. It was found in practice that walls which were perfectly tight in summer developed cracks of considerable area in winter. These were stopped by packing them with oakum dipped in cement, which required renewal every winter.

Messrs. Flad, Crosby, Johnson, Russell and Bryan participated in the discussion.

Civil Engineers' Society of St. Paul.

October 7, 1895.—A regular meeting of the Civil Engineers' Society was held at the Society room at 8.15 p.m. Vice-President Hilgard presided. Fourteen members and eleven visitors were present.

Minutes of previous meeting were read. An invitation from M. Jules Lermina, Secretary, to join the International Literary and Artistic Association, was referred to Mr. Estabrook and Mr. Münster.

The Committee Report of the Board of Regents of the University of Minnesota on the State Survey, was placed on file.

A communication from Mr. Thomas Egleston, touching a standard metric wire gauge, was referred to Messrs. Crosby, Lyon, Hogeland, Toltz and Merryman.

A memorial circular from Secretary F. R. Hutton, of the Am. Soc. M. E., on the death of President Davis, was referred to Mr. Lyon and Mr. Crosby.

A letter of instruction as to the preparation of matter for the Journal of the Association was placed on file.

A letter from Chairman J. B. Johnson, asking proposals for Journal exchanges, was referred to Mr. Münster and Mr. Woodman.

The Secretary was instructed to reply to the invitation of the Western Society of Engineers to attend the excursion of October 12th to the Drainage Canal.

Mr. Hew Miller was elected to membership.

Mr. A. O. Powell read an interesting and fully illustrated paper on Sluice Gates and Movable Dams of the Bear-Trap Type. The bear-trap gate is an American device of eighty years ago, but lately modified and improved. The French condemned it after an experimental trial of a gate wrongly proportioned, apparently considering it unworthy of scientific study. Mr. Powell has investigated the bear-trap gate mathematically, and will prepare his paper for publication in the Journal of the Association.

Mr. R. A. Lang, of Eau Claire, Wis., a builder and inventor of bear-trap gates of eighteen years' experience, briefly touched on a few points of interest, after which the meeting adjourned to Neuman's, at 11 o'clock, to spend a pleasant social hour.

C. L. Annan, *Secretary.*

Civil Engineers' Club of Cleveland.

Meeting of the Civil Engineers' Club of Cleveland, October 8, 1895.—Present, thirty-two members and friends. Minutes read and approved.

Messrs. C. M. Barber and C. F. Lewis were appointed tellers to canvass ballots for the election of Mr. George S. Rider and Frank A. Smythe.

Communications from the Board of Managers of the Associated Societies were read. They referred to the withdrawal of the Western Society from the Association, and to the new rules proposed for governing the management of the Journal, agreeable to the late voting of the members of the Societies.

The report of the Executive Committee was read, telling of the proposition of the Library Board to turn over our library to the care of The Case Library. After some discussion, the Club voted to do so. The Secretary was directed to send cards to the members, telling of the invitation from the Western Society to visit the Drainage Canal, and to extend our thanks to the Society for their kind invitation.

Messrs. George S. Rider and Frank A. Smythe were declared elected to active membership.

Prof. J. W. Langley, of the Case School of Applied Science, then gave a talk upon the Electrical Purification of Sewage. He told of the practical success of the system, where now in use, and gave figures from his own experiments, showing its economy.

He was followed by Prof. Benjamin, of Case School, with a brief and interesting paper upon "The Development of Mechanical Science in the World's History."

The Club then adjourned to the Hamilton Restaurant and participated in a light lunch.

F. A. Coburn, *Secretary.*

Boston Society of Civil Engineers.

October 16, 1895.—A regular meeting was held at the Society rooms, 36 Bromfield Street, Boston, at 7.50 p.m. President Noyes in the chair. Eighty-three members and visitors present.

The record of the last meeting was read and approved.

Messrs. Frank S. Badger, Harry C. Bradley, John R. Burke, Alfred D. Flynn and William E. McKay were elected members of the Society.

The Committee on Weights and Measures submitted a report recommending the adoption of the following resolution:

Resolved, That the Boston Society of Civil Engineers earnestly deprecate the use of any of the wire and sheet metal, or other trade gauges now in vogue, and strongly urge the use of millimeters and decimal fractions thereof for all such measurements.

The report was received and action on the resolution deferred until the next meeting.

The amendment to By-law 1, proposed at the last meeting, changing the night of the regular meetings from Wednesday to Friday, was not adopted.

The President reported that an agreement had been reached with the Trustees of the new Tremont Temple for the leasing of rooms for the Society's use, and that arrangements had been made with the New England Water Works Association and the Hersey Manufacturing Company for the joint use of these rooms. On motion, the President and Treasurer were authorized to execute a lease for these rooms, in accordance with the terms reported by the President.

Mr. J. A. Tilden, for the committee appointed to prepare a memoir of John H. Webster, submitted its report, which was read and accepted.

The thanks of the Society were voted to Lt.-Col. S. M. Mansfield, Corps of Engineers, U. S. A., for courtesies shown its members on the occasion of the visit to the Government Battery at Winthrop.

Mr. Allen Hazen then read the paper of the evening, entitled "The Present European Practice in Regard to Sewage Disposal." The paper was discussed by Messrs. Fitzgerald, Porter and others. Adjourned.

S. E. Tinkham, *Secretary.*

John H. Webster.—A Memoir.

By James A. Tilden and John R. Freeman, Committee of the Boston Society of Civil Engineers.

[Read October 16, 1895.]

It is with deep regret that we have to record the death of Mr. John H. Webster, a member of the Boston Society of Civil Engineers and also of the American Society of Mechanical Engineers. He passed away April 2, 1895, in the House of the American Society in New York, where he made his home when in that city. He was very nearly forty-five years of age, in the prime of life and at the period of his greatest value to the profession. The end found him at what he felt to be his post of duty, regardless of his physical condition; he was, as afterwards appeared, dangerously ill when he left his home in Boston for New York, two days before. His engineering work was almost his only recreation, and upon this he was habitually engaged from early in the morning until far into the night, so that when pneumonia overtook him it found him completely worn out and an easy victim.

As an engineer he was unusually able and energetic; as a gentleman he was entirely honorable and unassuming; and as a friend he was absolutely steadfast and true. He was most essentially a self-made man, as a reading of his application papers for membership to the engineering societies will show. His rare mechanical and inventive talent was first discovered and brought out when he was but nineteen years of age by Mr. L. D. Hawkins, and for six years thereafter he was engaged by that gentleman and others in designing general machinery. At the age of twenty-five he was engaged as head draughtsman in the reconstruction of the Standard Sugar Refinery of this city, at twenty-seven he became the Assistant Superintendent, and at thirty the Superintendent of the Refinery, in which position he remained for about ten years, making many valuable improvements for the refinery, and a reputation for himself.

At the organization of the American Sugar Refining Company in 1890, into which the Standard, among other refineries, was merged, Mr. Webster was made one of the Consulting Engineers, with headquarters in New York, dividing his time weekly between that city and Boston. This was the position he held at his death.

His whole life was an honor and a credit to the engineering profession, and what he gave to the world in design and invention are lasting monuments to his memory.

Montana Society of Civil Engineers.

Helena, Mont.—At the last meeting of the Montana Society of Civil Engineers, held Saturday evening, October 12th, in the rooms of the Society in the annex of the Granite Block, Mr. Keerl, who was appointed to confer with the librarian of the public library with reference to the best books on the subject of engineering that could be secured for the library, made a report. He said that he had given the subject a good deal of attention, and had recommended certain books which he hoped would be secured at an early date. He realized, he said, that the selection of a limited number of books on so comprehensive a subject was a matter for serious consideration, but he hoped that the selection he had made would meet with the approval of the Society.

It was voted that the Society donate to the library six volumes of the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, which would put the library in possession of all the copies of the JOURNAL since 1888.

A letter from Prof. J. B. Johnson, Chairman of the Board of Managers of the Association of Engineering Societies, was read, which contained the information that the Western Society of Engineers, of Chicago, had voted to withdraw from the Association. Prof. Johnson also called attention to the fact that new officers of the Association would soon be elected, and that, owing to other duties, he would be compelled to decline a renomination. This was much regretted by all, as they all realized that Prof. Johnson had been untiring in his efforts to promote the good of the Association.

A committee consisting of Elliott H. Wilson, of Butte; Edward R. McNeill, of Boulder, and Charles G. Griffith, of Helena, was appointed to nominate officers for the ensuing year.

The members present were: James S. Keerl, W. A. Haven, John Herron, A. E. Cumming, H. V. Wheeler, James H. Henley and F. J. Smith.

Bradley & Poates, Engr's, N.Y.

Association of Engineering Societies.

Vol. XV. | **November, 1895.** | No. 5.

PROCEEDINGS.

Western Society of Engineers.

The 334th Meeting of the Society was held in the Society's rooms, Wednesday evening, October 2, 1895. President Horton in the chair and forty-one members and guests present.

The minutes of the meetings of September 4th and 24th were read and approved.

The Secretary reported for the Board of Directors as follows:

At the meeting of the Board of Directors held September 7, 1895, the resignation of Mr. Benezette Williams as a representative of the Western Society of Engineers on the Board of Managers of the Association of Engineering Societies was read and accepted, and Mr. Charles J. Roney has been since appointed to serve the remainder of the unexpired term.

The following persons were elected to membership:

As Members—Messrs. John C. Bley and James C. Long.

The Treasurer reported a balance on hand September 1, 1895, of $1,599.43.

Bills to the amount of $138.83 were approved and ordered paid.

At the meeting of the Board of Directors held October 1, 1895, the following applications for membership were received and placed on file:

As Member—Lyman Smith, Chicago.

As Associate—Rudolph Link, Chicago.

Bills to the amount of $187.06 were approved and ordered paid.

Mr. Gerber, chairman of the Excursion and Entertainment Committee, announced a proposed Drainage Canal Excursion for October 12th, by special train to Lemont, thence returning, stopping at various points; luncheon to be served at some point on the trip; further announcements to be made.

On motion, after explanation of the need of such action, it was *Resolved*, That a committee of three be appointed by the chair, to report at the next regular meeting of the Society (November 6, 1895), a plan for the publication of the papers and proceedings of the Society and a revision of the Constitution and By-Laws.

The Secretary announced the death, a few hours previously, of General O. M. Poe, Col. of Engineers, U. S. A., one of the oldest members of the Society, and a committee was appointed to draft appropriate resolutions thereupon,

The Secretary reported the list of delegates from the Western Society of Engineers to the First Annual Convention of the International Deep Waterways Association, at Cleveland, Ohio, September 24, 25, 26, 1895, as follows: Members—Gen. O. M. Poe, Lyman E. Cooley, Isham Randolph, Thos. T. Johnston, Alex. E.

Kastl and Ebin J. Ward. Associates—Frank Wenter, William Boldenweck, Bernard A. Eckhart, and Capt. James S. Dunham. All these delegates attended the Convention, except Gen. Poe, who was unable to do so.

On motion the chairman was instructed to appoint delegates from the Western Society to the Western Waterways Convention at Vicksburg, Mississippi, October 22 and 23, 1895. Messrs. Lyman E. Cooley and Thomas T. Johnston were subsequently appointed delegates.

A memoir of Warren Collier Smith was read, ordered spread upon the records of the Society, and a copy sent to the family of the deceased.

A discussion on "The Proper Chemical Composition of Steel for Heavy Rail-sections" was then opened by Mr. Robert W. Hunt, and a very interesting presentation of the subject was made. The meeting then adjourned.

On Saturday, October 12th, a very delightful excursion was made to various points of interest on the Chicago Sanitary Drainage Canal. By the courtesy of the Chicago & Alton Railroad Company a special train was secured, and a luncheon was served on the train. About 225 members and guests, including many ladies, participated.

At the meeting of the Board of Directors, held October 15th, the following applications for membership were received and placed on file.

As Members: Waldo H. Marshall, Mechanical Engineer, and Editor of the *Railway Master Mechanic*, Chicago, and Charles Woodbury Melcher, Mechanical Engineer, and Chicago Manager The Ingersoll-Sargeant Drill Co., Chicago.

CHARLES J. RONEY, *Secretary.*

Warren Collier Smith.—A Memoir.

BY ISHAM RANDOLPH, FREDERICK S. BROWN AND JAMES J. REYNOLDS,
COMMITTEE OF THE WESTERN SOCIETY OF ENGINEERS.

[Read October 2, 1895.]

THE subject of this memoir, Warren Collier Smith, was born in Clark County, Va., on June 28, 1866. His parents were Warren Christian Smith and Betty B. Smith (*née* Randolph.) The home influences which surrounded the boy were such as tend to the up-building of a sturdy, honest and honorable character, and they bore fruit in him of the truest manhood.

The circumstances of his life debarred him from a broad and liberal education, but such educational advantages as were vouchsafed him he improved faithfully, grounding himself well in the English branches and in the basic principles of mathematics.

In 1886, he secured employment in the Engineer Corps of the Chicago, Madison and Northern Railroad in a very subordinate position. His steady, industrious habits and close observation, coupled with his aptness to learn, attracted the attention of his superiors, who extended to him the opportunities which he needed of becoming familiar with the use of instruments and acquiring practice in the computations of field and office.

Upon the completion of that work, he secured employment in West Virginia, on railroad location and construction, in a responsible capacity. Later, he was

employed upon the Chicago and Eastern Illinois Railroad, in charge of the second track graduation between Dalton and Momence. After this, he was engaged upon the surveys and construction of the Chicago and Calumet Terminal Railroad. Following this, he entered the employ of Mr. W. F. Sargent, Engineer and Surveyor of this city, and, for the last three years of his life, he was associated with his uncle, Isham Randolph, in charge of the land survey branch of his business.

He was quiet and unassuming, but forceful and determined, a man who impressed all with whom he come in contact, either in the business of life or in its friendly relations, with his unfaltering integrity, his high sense of honor and his kindliness of heart. To us who knew him in the daily intercourse of life, he was genial and affectionate, a friend to be loved and trusted in life, and sincerely mourned in death.

He died on the 29th of March, 1895, at the home of his mother in Jefferson County, West Virginia, leaving a short record of years, full of honest, earnest work and loyal devotion to duty and friendship.

Engineers' Club of Minneapolis.

October 14, 1895—A special meeting, to which other engineers of Minneapolis had been invited by the Engineers' Club of Minneapolis, was held at the office of the City Engineer, City Hall, to take action upon the death of William A. Pike, C. E., which occurred on Sunday, October 12, 1895.

The meeting was called to order at 8 p.m. by the President, F. W. Cappelen, who in fitting words announced the great loss which both the Club and the profession had sustained, after nearly all present had paid fitting tribute to our deceased member. I. E. Howe moved that a committee of three be appointed to draft suitable resolutions and present them to this meeting for adoption. This was amended, increasing the committee to five, and adding "and that this committee make arrangements for flowers, and attend the funeral as representatives of this meeting," and so carried.

The Chair appointed, as such committee, I. E. Howe, M. D. Rhame, E. T. Abbott, Wm. De La Barre, and Elbert Nexsen.

The following resolutions were drawn up, reported and unanimously adopted:

Whereas, Death has removed from our midst an esteemed associate and friend in the person of William A. Pike, and we wish to express our appreciation of him as a man and civil engineer.

Resolved, That we do hereby express our sincere sorrow at the death of William A. Pike, feeling that in him the engineering profession had a faithful and able representative, whose character and abilities gave promise of a most useful and honorable future. In him we recognized such strongly marked traits of character, such high aims, such devotion to his profession, such honesty of purpose as to win our admiration and command our highest respect.

We extend our sympathies to the wife and family of our departed colleague, realizing that a great personal loss has been sustained by those intimately associated with him in his lifetime.

Resolved, That an engrossed copy of these resolutions be transmitted to his bereaved family.

Elbert Nexsen, *Secretary*. F. W. Cappelen, *President*.

On motion, adjourned.

Elbert Nexsen, *Secretary*.

NOVEMBER 22, 1895.—A meeting of the Engineers' Club of Minneapolis was held at the office of the City Engineer, City Hall, at 8 P.M., the President in the chair, to consider the advisability of continuing the Club next year, or winding up its affairs with this year.

A statement was made showing the indebtedness of the Club, which was entirely due to the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES. A canvas of the amounts due from members showed that this had arisen by neglect of members to keep their assessments paid up—that there was enough due which was considered good to meet our liabilities. The sentiment expressed by all present was that this must be collected and the debt paid early in December, and that the Club had better die than drag along as it had for the last few months.

W. R. Hoag moved a committee of three be appointed to see all members in arrears, and point out to them that this debt must be paid at once, and unless they paid up their arrearages those who had must do it for them. Carried. Chair appointed W. R. Hoag, F. W. Cappelen and Elbert Nexsen, committee.

The Secretary read a letter from Mrs. Maria R. Pike, expressing her thanks and those of her family for the action of the Club in reference to the death of her husband, Mr. William A. Pike.

Adjourned, subject to the call of the President.

ELBERT NEXSEN, *Secretary.*

Technical Society of the Pacific Coast.

NOVEMBER 1, 1895.—Regular meeting. Called to order at 8.30 P.M., by President Dickie.

The minutes of the last regular meeting were read and approved.

The following gentlemen were elected to membership by regular ballot:

Members.—W. F. Englebright, Dana Harmon and W. W. Waggoner, all of Nevada City, California.

The proposition for membership of Dr. Willis E. Everette, Mining Engineer of Tacoma, Washington (proposed by George F. Schild, H. C. Behr and Otto von Geldern), was referred to the Executive Committee.

Professor Frank Soule then read the paper of the evening, entitled :

"Pacific Coast Timber, Its Tests and Treatment," which was fully discussed by members present.

Adjourned. OTTO VON GELDERN, *Secretary.*

Civil Engineers' Society of St. Paul.

NOVEMBER 4, 1895.—The regular meeting of the Civil Engineers' Society of St. Paul was called to order at the Society library at 8.30 P.M., by Vice-President Hilgard.

Present, eleven members and six visitors.

Minutes of previous meeting read and approved.

An adverse report of the Committee on International Literary and Artistic Association was accepted and committee discharged. All other committees were granted an extension of time.

Resolutions of thanks for courtesies extended to members of the Society were

passed in favor of the Western Society of Engineers, F. W. Cappelen, City Engineer of Minneapolis, and the Twin City Rapid Transit Co.

Messrs. Powell, Loweth and Woodman reported a resolution in favor of surveying the upper Mississippi, and the Secretary was instructed to telegraph the same to the Mississippi River Commission, at St. Louis, Mo.

Mr. Potts described the rebuilding of the Ketter River bridge approaches destroyed by the Hinkly fire. The remarkable record of framing and erecting an average of 100,000 feet of lumber per day was accomplished on this work.

Mr. Hilgard illustrated the method of hydraulic grading in vogue on the N. P. R. R. system. Under favorable circumstances the work of replacing worn-out wooden trestles with embankments is done at a cost of five cents per cubic yard.

Adjourned at 10.45.

C. L. Annan, *Secretary.*

Engineers' Club of St. Louis.

424th Meeting, November 6, 1895.—The club was called to order at 8.20 p.m., at 1600 Lucas Place, President Russell in the chair. Twenty-two members and five visitors present. The minutes of the 423d meeting were read and approved. The Executive Committee reported the doings of its 198th meeting, approving the application for membership of S. E. Freeman. He was balloted for and elected. Applications for membership were announced from Carl Barth, engineer Ranken & Fritsch Foundry and Machine Co.; Alfred W. French, Civil Engineer United States Government, Jefferson Barracks; and Richard Morey, City Engineer, Sedalia, Mo.

The Secretary announced the receipt of a detailed financial statement from the Secretary of the Association of Engineering Societies.

Prof. Chas. C. Brown's paper on "The Sewerage of Indianapolis" was then read by Mr. B. H. Colby. The paper explained the peculiar features of the problem, and was illustrated by drawings and maps showing the general features, as well as details of the several interesting forms of special construction. The methods of carrying on the work, and its extent and cost, were explained. The country being flat, little or no fall was available.

The discussion was participated in by Messrs. Robert Moore, Kineally, Flad, Olshausen, J. B. Johnson, Sherman, Pitzman, Hermann, Maltby, Bouton and President Russell.

Mr. Moore gave some further details of the situation, size of streams, etc. The life of iron work painted with asphalt was discussed. The difficulty of getting good construction in masonry was mentioned, as was also the subject of water pollution and protection of water sheds.

Adjourned. William H. Bryan, *Secretary.*

425th Meeting, November 20, 1895.—President Russell called the club to order at 8.25 p.m., twenty-six members and eight visitors being present.

The minutes of the 424th meeting were read and approved. The Executive Committee reported the doings of its 199th meeting. The names of John Dean, J. L. Duffy and J. A. Tiernan were dropped for delinquency. The applications for membership of C. G. L. Barth, Richard Morey and A. W. French, were approved. They were balloted for and elected.

On motion of Prof. J. H. Kinealy, the following parties were chosen a Committee on Nominations of Officers for 1896: E. D. Meier, P. N. Moore and William Bouton.

Resignations were announced from R. F. Grady and B. J. Arnold.

Prof. W. B. Potter, chairman of the club's Committee on Smoke Prevention, then addressed the club informally, explaining the steps which had brought about the present status of affairs in smoke abatement. The original agitation was begun in this club, and had resulted in the passage of two ordinances which had been in force for over two years, and were operating very satisfactorily. The movement had the backing of a popular organization known as the Citizens' Smoke Abatement Association, supported by nearly two thousand members. A Government official, who had recently investigated the subject, had reported that St. Louis had stopped 70 per cent. of its smoke, and was doing better than any other city in the country. The Professor explained the methods of measuring smoke and suggested that Government observers keep records of the smokiness of the atmosphere on different days. He also spoke of smoke from house chimneys, and the remedies possible. He then devoted special attention to the steam jet, as it is a very cheap remedy. He called attention to the fact that the personality of firemen entered more largely into this matter than any other single feature,.and suggested that it would be well to license firemen, and thus raise the grade of intelligence and secure better results. A great many plants were defective in draft and had large air leakages. The attention which had been given the smoke problem had resulted in better boiler practice generally. The Professor thought that, on the whole, good progress had been made in the movement, and still better results could be expected in the future.

The discussion was participated in by Messrs. J. B. Johnson, P. N. Moore, Flad, Olshausen, Meier, Sherman, Bryan and Kinealy.

Adjourned. William H. Bryan, *Secretary.*

Civil Engineers' Club of Cleveland.

November 12, 1895.—Meeting of the Civil Engineers' Club of Cleveland, called to order by President Mordecai at about 7.45. Present, fifty-four members and visitors.

Minutes of the last meeting read and approved. Minutes of the Executive Committee meeting read and the resignation of Mr. W. W. Read reported.

Professor C. H. Benjamin reported in regard to the proposed excursion to Niagara Falls, and upon his motion a committee was appointed to attend to the matter.

The paper of the evening, by Mr. Frank C. Osborn, on Bridge Floors, was read, on account of his absence from the city, by his assistant, Mr. Bernard S. Green.

Mr. Osborn treated the subject historically, noting the progress in the design of the solid floors abroad and at home from the earliest times to the present. He states that the first bridge on record with solid wrought-iron floor is the Britannia, built in 1845. In America, the oldest solid iron trough floor for railroad bridge is that over the Willamette River, built in 1887.

Mr. Osborn gives the successive dates of introduction of about all the various forms that have now been in use, and brief description of the most important. He gives the requirements for a good railroad bridge floor as follows: Accessibility for

examination and painting, facilities for thorough and rapid draining, the use of shapes and sizes readily obtainable from the mills, simplicity of shop construction, cheapness of first cost and cost of maintenance, convenience of changing location of track laterally and direct, simple and effective connection to girders.

Discussion by Messrs. E. A. Handy, A. E. Brown and others.

Messrs. C. H. Benjamin, James Ritchie and E. S. W. Moore were appointed to arrange the Niagara Falls excursion.

The Club adjourned to the restaurant and partook of a light lunch.

FORREST A. COBURN, *Secretary.*

Boston Society of Civil Engineers.

NOVEMBER 20, 1895.—A regular meeting of the Society was held at its rooms, 36 Bromfield Street, Boston, at 7.50 P.M., President Albert F. Noyes in the chair- Sixty-nine members and visitors present.

The record of the last meeting was read and approved.

Messrs. Dwight L. Hubbard, Willis T. Knowlton, Elmer G. Manahan, Charles W. Sherman, George A. Soper, and Charles Temperley, were elected members of the Society.

The thanks of the Society were voted to Samuel Nott, an honorary member and Secretary of the Society from 1849 to 1874, for his gift of valuable books to the library.

The Treasurer spoke of the plan of raising a fund for fitting up the new rooms of the Society, by voluntary subscription, and stated that two liberal contributions had been received already. On motion it was voted that an appeal for subscriptions to the fund be issued in the notices of the next meeting.

The resolution submitted at the last meeting by the Committee on Weights and Measures, in relation to a uniform standard of thicknesses for metals, was then considered, and after discussion, was amended so as to read :

Resolved, That the Boston Society of Civil Engineers earnestly deprecates the use of any of the wire and sheet metal, or other trade gauges now in vogue, and strongly urges the use of a decimal system for all such measurements.

Mr. R. W. Lesley, Treasurer of the American Cement Company, of Philadelphia, was then introduced, and read a paper entitled "Progress of the Manufacture of Portland Cement in America."

At the conclusion of the discussion of the paper, in which the members quite generally took part, a vote of thanks was passed to Mr. Lesley for the interesting paper which he had so kindly read.

Adjourned. S. E. TINKHAM, *Secretary.*

Bradley & Poates, Engr's, N.Y.

ASSOCIATION OF ENGINEERING SOCIETIES.

VOL. XV. DECEMBER, 1895. No. 6.

PROCEEDINGS.

Western Society of Engineers.

THE 335th meeting of the Society was held in the Society's rooms, 1737 Monadnock Block, Chicago, on Wednesday evening, November 6, 1895. President Horton in the chair, and 40 members and guests present.

The minutes of the meeting of October 2d were read and approved.

The Secretary read the report of the Board of Directors—

At the meeting of the Board of Directors, held October 15, 1895, the following applications for membership were received and placed on file:

As Members—Messrs. Waldo H. Marshall and Charles Woodbury Melcher, both of Chicago.

At the meeting of the Board of Directors, held November 5, 1895, the following applications for membership were received and placed on file:

As Members—Messrs. Carl Haller, William T. Keating, LeRoy Kempton, Sherman and Leland L. Summers, all of Chicago.

The following named persons were elected to membership in the Society:

As Members—Waldo H. Marshall, Charles Woodbury Melcher and Lyman Smith, all of Chicago.

As Associate—Rudolph Link, Chicago.

The Treasurer reported a balance on hand October 1, 1895, of $1,561.79; and a balance on hand November 1, 1895, of $1,444.69.

Bills to the amount of $476.64 were approved and ordered paid.

Mr. Gerber, Chairman of the Excursion and Entertainment Committee, read an invitation from the Pioneer Rail Renewing Co., of Chicago, by Mr. James S. Prentice, Treasurer, inviting the Society to visit the works of that Company (formerly the North Chicago Rolling Mill Co.), on the 9th or 16th instant, preferably the 9th instant, and the invitation was accepted for that date.

Mr. Johnston, Chairman of the Committee, presented the following report:

"Your committee appointed to prepare a plan for the publications of the Society, and a revision of the Constitution and By-Laws, respectfully make report as follows:

"1. A draft of a resolution is submitted herewith, which, if adopted by the

Society, formulates a plan for publication. It is practically the rules under which the Philadelphia Society is proceeding, and which has been found satisfactory.

"2. A draft of a revised Constitution and By-Laws is submitted. The committee feels that the existing Constitution and By-Laws are very deficient, and recommends urgently the careful consideration of the document submitted, believing confidently that, though it may be in some respects imperfect, it certainly will be an exceedingly desirable substitute for what now exists."

(Signed) THOS. T. JOHNSTON,
CHAS. E. BILLIN.

Mr. Charles J. Roney, the third member of the Committee, briefly dissented, but from lack of time was unable to present a minority report.

It was voted that the report of the Committee be received for discussion.

The following resolution was presented, seconded and adopted :

"*Resolved*, That the report of the Committee on plans for publications and a revision of the Constitution and By-Laws be received, accepted and the Committee continued ; and, be it further

"*Resolved*, That the draft of the revised Constitution and By-Laws be printed and copies sent to all members of the Society at once, and that the matter be further considered at the adjourned meeting to be held on Friday, November 15, 1895, at 8 P.M."

The Secretary announced the death of Mr. Willard S. Pope, a Past President of the Society and one of its oldest members, who died, October 10th, at his home in Detroit, Mich.

On motion, it was voted that the President should appoint a Committee to prepare a memorial of our deceased member, Mr. Pope.

The President subsequently appointed as such Committee Messrs. George S. Morison, L. P. Morehouse and E. C. Carter.

The subject for discussion for the evening, "Methods of Power Testing for Motocycles," was introduced by Mr. Leland L. Summers, in a very interesting and instructive review of the general subject of motocycles, followed by a description by Mr. John Lundie of the machine and methods employed in testing motocycles to be used in the forthcoming motocycle contests in Chicago and vicinity. After an animated discussion of the subject, the meeting adjourned to meet in the Society's rooms on Friday, November 15, 1895, at 8 P.M.

CHARLES J. RONEY, *Secretary.*

ON Friday evening, November 15, 1895, the Society met pursuant to adjournment. President Horton in the chair and 25 members present.

It was moved and seconded that the resolution providing for publications be adopted. An amendment was offered that the third paragraph be stricken out. On vote the amendment was lost. The resolution was then by vote adopted.

On motion, the proposed revision of the Constitution, previously printed and mailed to members, was taken up for informal consideration, article by article, and in some cases section by section, and after such amendments as were approved, the articles were severally seconded by the meeting.

Articles I and II of the proposed revision of the By-Laws were in like manner considered, and, after amendment, were seconded by the meeting.

A resolution was then adopted that when the meeting adjourned it should adjourn to meet in the Society's rooms on Friday, November 22, 1895, at 8 P.M., for further consideration of the proposed revision of the Constitution and By-Laws.

Mr. George S. Morison here offered as an amendment to Article VI (by error printed as Art. IV), the following addition to Section 5 of said Article VI: "Any active member elected prior to December 31, 1895, and who shall have paid all fees, dues or assessments which may have accrued against him for a continuous period of twenty years (dues paid to the Civil Engineers' Club of the Northwest to be included in reckoning such twenty years), shall be excused from payment of annual dues thereafter," and asked that the same be considered at the next meeting.

On motion, the meeting then adjourned to meet in the Society's rooms on Friday, November 22, 1895, at 8 P.M. CHARLES J. RONEY, *Secretary.*

A SPECIAL meeting (336th of the Society) was held in Science Hall, Armour Institute of Technology, Chicago, on Thursday evening, November 21, 1895, at 8 o'clock. President Horton in the chair and 51 members and guests present.

A paper, "Application of Electric Power to Industrial Purposes," was presented by the author, Mr. George P. Nichols. The paper was illustrated by some thirty fine lantern views, and ofter discussion of the paper the meeting adjourned.

CHARLES J. RONEY, *Secretary.*

ON Friday evening, November 22, 1895, the Society met in the Society's rooms pursuant to adjournment from November 15th. Vice-President Johnston in the chair and 14 members present.

It was voted that a committee of ten members be appointed by the President to nominate candidates for the offices to be filled at the next annual election of the Society.

The meeting then proceeded to further consideration of the proposed revision of the Constitution and By-Laws, beginning at Article III of the By-Laws.

Articles III to VIII, inclusive, were considered, and after such amendments as were adopted, these articles were seconded by the meeting. The Amendment to Article VI, Section 5, proposed by Mr. George S. Morison at the meeting of November 15th, was voted upon and was rejected. Article IX was stricken out.

It was moved by Mr. Reynolds that the Constitution and By-Laws be seconded as a whole. Motion seconded and carried. The meeting then adjourned.

CHARLES J. RONEY, *Secretary.*

On November 9, 1895, by invitation of the Pioneer Rail Renewing Company, of Chicago, the works of that Company were visited and inspected by a considerable number of members. The Gates Iron Works were also visited, and the system of operation was fully inspected.

THE 337th meeting of the Society was held in the Society's rooms, 1737 Monadnock Block, Chicago, on Wednesday evening, December 4, 1895, at 8 P.M., with 41 members and guests present.

In the absence of the President and both Vice-Presidents, Mr. Alfred Noble was elected President *pro tempore.* The presentation and approval of the minutes of the November meetings of the Society, and the report of the Board of Directors were passed.

Mr. G. A. M. Liljencrantz, Chairman of the Committee, read a memoir of our deceased member, General O. M. Poe, and presented a series of resolutions regarding the death of General Poe, which resolutions were adopted by the Society. The memoir and resolutions will appear in the first number of the new journal of the Society.

A request for a better ballot on the proposed revision of the By-Laws of the Society, as amended at the November 6th meeting of the Society, was made by Messrs. Charles E. Billin, James J. Reynolds, Wm. T. Casgrain, G. A. M. Liljencrantz and P. H. Ashmead, and the Chairman announced that the requisite number of members having made such request, a letter ballot would be taken.

Mr. Clement F. Street, manager of the *Railway Review* engineer of the recent commission from the Field Columbian Museum, to visit Oriental railways, was then introduced and in a very entertaining manner presented notes of his observations of the engineering characteristics of the railways of Oriental countries, accompanied by the exhibition of a large number of photographs. A full report of Mr. Street's paper will appear in the new journal of the Society.

After a vote of thanks to Mr. Street, the meeting adjourned.

CHARLES J. RONEY, *Secretary.*

A SPECIAL meeting (338th of the Society) was held in the Society's rooms, on Thursday evening, December 19, 1895, at 8 P.M. President Horton in the chair and 26 members and guests present.

A paper, "Engineering Consequences of the Waterway Conventions at Cleveland, O., and Vicksburg, Miss., in 1895," was presented by Mr. Thos. T. Johnston, and the subject was very fully discussed by Messrs. F. P. Kellogg, L. E. Cooley, Isham Randolph, E. L. Cooley, Geo. A. Lederle, Chas. L. Harrison and Thos. T. Johnston.

It was voted that a committee be appointed to prepare a suitable expression to the President and faculty of the Armour Institute of Technology for the courtesies extended to the Society during the past year, and Mr. Isham Randolph was appointed as such committee.

Adjourned. CHARLES J. RONEY, *Secretary.*

NOTE.—At the meeting of the Board of Directors, held December 3, 1895, the following applications for membership were received and filed: As Member—John C. Ostrup, Chicago. As Junior—Stillman Bingham Jameison, Chicago.

At the meeting of the Board of Directors, held December 19, 1895, the following applications for membership were received and filed: As Associates—James W. Gardner and Joseph S. Qualey, both of Chicago.

PUBLICATIONS.

The Publication Committee has reported to the Board of Directors that, for 1896, they will publish a journal containing about ninety pages of reading matter in each of six numbers. They have in sight a revenue from advertisements at this day sufficient to cover all probable expense of the publications for the year. They have entered into a contract for the work, and expect to have the first number out about the middle of January, 1896. The Committee reports that it is secure in regard to good matter for the journal, the contents of which will come under three general heads, as follows:

I. Papers and Discussions.
II. Topical Discussions.
III. Abstracts from Foreign Technical Papers.

CHARLES J. RONEY, *Secretary.*

Association of Engineers of Virginia.

THE regular fall meeting of the Association of Engineers of Virginia was held in Roanoke on Saturday, November 23d, at 3 P.M. The meeting was called to order by the President, Mr. J. C. Rawn.

A paper by Prof. D. C. Humphreys, of Lexington, Va., on "Stream Measurements and Water Power in Virginia and West Virginia," was read by the Secretary (in the absence of Prof. Humphreys). The paper was particularly interesting to those of this section of the State. Referred, on motion, to the Publication Committee.

A paper was read by Prof. L. S. Randolph, of Blacksburg, Va., on "Cement Testing," special attention being given to the effects of heat. The results were interesting in showing that some cements increased and some decreased in strength from the effects of continned heat. Referred, on motion, to the Publication Committee.

Mr. J. C. Rawn gave a report of the Good Roads Convention, which met in Richmond in October, which report was very encouraging in that it showed a general interest all over the State in this very important matter.

Mr. M. E. Yeatman moved to amend Article IX of our Constitution and Rules, changing the first clause from "These rules may be amended at any annual meeting by a two-thirds vote of the members present, *not less than fifteen voting in the affirmative*," by leaving out the part in italics.

Mr. Wm. M. Dunlap moved that Article I of the Constitution be changed so as to read, "This Association shall be called 'The Association of Engineers of the Virginias.'"

Under the Constitution these two motions will have to lay over until the annual meeting in January, and then decided.

Mr. S. A. White moved that a committee be appointed, with power to act, to investigate the matter of State laws in reference to the securing of claims for engineering services.

Motion carried, and Mr. S. A. White, Mr. Wm. M. Dunlap and Mr. H. A. Gillis were appointed on this committee.

JNO. A. PILCHER, *Secretary.*

Engineers' Club of St. Paul.

ST. PAUL, DECEMBER 2, 1895.—A regular meeting of the Civil Engineers' Society of St. Paul was called to order by President Stevens at 8.15 P.M. Present, eleven members and one visitor.

Minutes of previous meeting read and approved.

Mr. James D. Du Shane was elected a member.

The evening programme was necessarily waived, but several members volunteered interesting information.

Mr. Davenport described the three classes of earth slides which occur along the Red River of the North. The most remarkable have taken place two or three years after great floods (such as those of 1882 and 1893), when suddenly vast masses of the banks, several hundred feet wide and from thirty to fifty feet high, sink abruptly, and from 150,000 to 250,000 yards of the deeply underlying clay strata slide into the river, there being no horizontal movement of the upper mass.

Mr. Hilyard mentioned the fact that a pier of the N. P. R. R. bridge, at Bismarck, glided twenty-seven inches out of position, presumably on a bed of clay moistened by leakage from the city reservoir.

Mr. Crosby described his recent impressions of the sugar plantations and levees above New Orleans.

Mr. Estabrook stated that a saving of about 20 per cent. has been effected by substituting a triple for a double expansion engine at the Washburn-Crosby flour mills in Minneapolis. C. L. ANNAN, *Secretary.*

Engineers' Club of St. Louis.

426TH MEETING, DECEMBER 4, 1895.—The annual meeting was held at 1600 Lucas Place, with twenty-three members and three visitors present.

President Russell called the Club to order at 8.30 P.M. The Executive Committee reported the doings of its 200th meeting. Applications for membership were announced from Walter S. Brown, S. F. Crecelius and Ora E. Overpeck.

The President read the annual report of the Executive Committee. It was approved and ordered filed. On motion it was ordered that the Executive Committee be authorized to arrange with the Missouri Historical Society for an extension of the present contract for a term not greater than three years, on the same or better terms than heretofore.

The annual reports of the Secretary and Librarian were then read, and, on motion, accepted and ordered filed.

The Treasurer read his annual report, which was, on motion, referred to the Executive Committee to be audited.

The Standing Committee on Eads Monument asked to be continued. So ordered.

The Committee on Boulevards submitted a report which was ordered received and the committee discharged.

The Committee on Library submitted a report. It was accepted and the committee continued.

At the suggestion of Mr. Bryan, the Committee on Boiler Legislation was discharged, and that on Standard Gauges for Thickness continued.

The Committee on Nominations of Officers for 1896 reported as follows:

For President—J. A. Ockerson.

For Vice-President—Edward Flad.

For Secretary—William H. Bryan.

For Treasurer—Thomas B. McMath.

For Librarian—W. A. Layman.

For Directors—S. B. Russell and Carl Gayler.

For Representatives on the Board of Managers of the Association of Engineering Societies—J. B. Johnson and W. E. Barns.

Additional nominations being called for, B. H. Colby and N. W. Eayrs were placed in nomination for Vice-President, and William Bouton, Julius Baier, M. L. Holman and B. L. Crosby for directors.

The Secretary acknowledged the receipt of a copy of the souvenir prepared by the local chapter of the American Institute of Architects at its recent convention in this city.

Ordered that the Executive Committee arrange for a supper on the evening of December 18th.

C. H. Sharman then read a paper prepared by R. J. McCarthy, of Kansas City, on the subject of smoke prevention, which paper had already been read by the author before the Engineers' Club of Kansas City. It was an able and exhaustive presentation of the subject, and was discussed at some length by Messrs. Bryan, Kinealy, Russell, and Wheeler. Ordered that the thanks of the Club be extended to both the author and reader of the paper.

Prof. J. H. Kinealy then exhibited a new form of draught gauge, which remedied many of the troubles incident to the ordinary forms of apparatus.

William H. Bryan, *Secretary.*

427th Meeting, December 18, 1895.—The annual dinner was given at the Mercantile Club, the hour of the meeting being 7.30 p. m. At 8.15, those present sat down to dinner, President Russell occupying the chair, with forty-five members and six visitors present.

After justice had been done to the dinner, President Russell called the club to order, after which the Secretary read letters of regret from: Horace E. Horton, President, Western Society of Engineers; A. F. Noyes, President, Boston Society of Civil Engineers; and Augustus Mordecai, President, Civil Engineers' Club of Cleveland. He then read the report of the 203d meeting of the Executive Committee, giving the result of the letter ballot for officers for 1896 as follows:

For President—J. A. Ockerson.

For Vice-President—Edward Flad.

For Secretary—William H. Bryan.

For Treasurer—Thomas B. McMath.

For Director—M. L. Holman.

For Librarian—W. A. Layman.

For Members Board of Managers of the Association of Engineering Societies—J. B. Johnson and W. E. Barns.

There having been no election for the second director, the committee ruled that the oldest director, Mr. Crosby, retire, and Mr. Bouton continue to serve until his successor was elected. On motion it was ordered that the matter of election of an additional director be deferred until the next meeting.

Retiring President Russell then resigned the chair in favor of the incoming president, Mr. J. A. Ockerson, who was seated at the opposite end of the table. After brief remarks, President Ockerson called on Mr. Russell for an address, which the latter then delivered, his subject being, "The Work of Engineers' Clubs." Other addresses were afterwards made as follows: "Engineers' Clubs, Their Best Fields of Usefulness," Robert Moore; "The Engineer at Home and Abroad," Julius Pitzman; "The Engineer of the Future," Richard McCulloch; "The Association of Engineering Societies," J. B. Johnson; "The Engineers' Club of St. Louis," C. M. Woodward.

Mr. George H. Reynolds, of Chicago, being called upon, made some brief remarks on "The Standing and Character of the Engineer." Adjourned.

William H. Bryan, *Secretary.*

Technical Society of the Pacific Coast.

Regular Meeting, December 6, 1895.—Called to order at 8.30 p.m. by President Dickie.

The minutes of the last regular meeting were read and approved.

Dr. Willis E. Everette, of Tacoma, Washington, was elected to membership by regular ballot.

The name of John Cotter Pelton, Architect, of San Francisco, was proposed for membership by H. T. Bestor, G. W. Percy and Otto von Geldern. Referred to the Executive Committee for action.

In compliance with Section 2, Article II, of the By-Laws, the following members were duly elected a Nominating Committee to present a ticket at the next regular meeting for the election of the Society's officers for the ensuing year:

John Richards,
C. E. Grunsky,
H. C. Behr,
A. d'Erlach,
Ross E. Browne.

Mr. Otto von Geldern explained to the members present the cyclotomic method of transit observations, introducing a novel instrument for the engineer's use in the field.

Mr. John Cotter Pelton then read the paper of the evening, entitled "Released Ashlar," submitting for discussion the problem of attaching slabs of marble to the exterior of the walls in building construction, in which the façade is simply ornamented to the extent of a marble or other finish.

This paper led to an interesting discussion, which occupied the evening of the meeting.

It was ordered, upon motion, that the paper be edited by the Technical Society and submitted for publication in the Journal of the Association of Engineering Societies. Adjourned.

Otto von Geldern, *Secretary.*

The Civil Engineers' Club of Cleveland.

Meeting of the Civil Engineers' Club of Cleveland in the Assembly Room of the School Council, December 10, 1895, called to order at 8 p.m. by President Mordecai. Present, eighty-seven members and visitors. On motion, the reading of the minutes was dispensed with.

Application of J. S. Covert for admission as Active Member was read. Report of the election of S. E. Tinkham as Chairman, and J. C. Trautwine, Jr., as Secretary of the Association of Engineering Societies, was read.

The speaker of the evening, Mr. Geo. De Leval, was introduced by the President, and read his interesting paper on "Crank and Fly Wheel versus Direct Compensating Pumping Engines," illustrated by reference to blue prints of different types and parts of engines.

Discussion was engaged in by Mr. H. G. H. Tarr, Mr. J. F. Holloway, and others.

Resolutions were adopted thanking the School Council for the use of their room for the evening, and thanking Mr. De Leval for his interesting lecture.

At 10 p.m. adjourned. F. A. Coburn, *Secretary.*

Montana Society of Civil Engineers.

HELENA, Mont.—The regular monthly meeting of the Montana Society of Civil Engineers was held Saturday evening, December 14th, at the society's headquarters in the Helena Board of Trade Rooms. The applications for membership of John Randolph Parks and John Cameron Patterson were read, and the Secretary was directed to send out letter ballots to the members, to be canvassed at the next regular meeting.

Charles G. Griffith was elected trustee, to fill the vacancy caused by the resignation of Walter S. Kelley.

A letter from Prof. J. B. Johnson, Chairman of the Board of Managers of the Association of Engineering Societies, was read. It stated that at the last election of the Board, S. E. Tinkham, of Boston, had been chosen Chairman, and John C. Trautwine, Jr., of Philadelphia, Secretary. President Keerl was selected to draw a set of resolutions expressing the appreciation of the socicty for Prof. Johnson's untiring work for the good of the Association during his term as Chairman.

Several members had sent written discussions of John H. Farmer's paper on Water Power by Electrical Transmission in Relation to the Mills and Manufactures of Helena, and it was expected these would be read at this meeting, but, owing to the importance of the subject, and to secure a fuller discussion, it was voted to have the paper and the discussions now on hand printed in full and sent to each member of the society and to others interested in the subject, with the request that they each send a written discussion to the Secretary in time for the annual meeting to be held in this city January 11, 1896, at which time a number of engineers from various parts of the State will be present. It is expected that a number of engineers will give this matter serious consideration, and their ideas reduced to writing will form a most interesting topic for discussion at the annual meeting.

The meeting adjourned to January 11, 1896.

F. J. SMITH, *Secretary.*

Boston Society of Civil Engineers.

DECEMBER 18, 1895.—A regular meeting was held at the Society rooms, 36 Broomfield Street, Boston, at 7.45 P.M. Past President, Frederic P. Stearns in the chair. Eighty-three members and visitors present.

The record of the last meeting was read and approved.

Messrs. Joseph S. Craigue, Arthur W. Dean, Arthur C. Grover, Joseph P. Lyon, Irving E. Moultrop, Franklin H. Robbins, George G. Shedd, Gordon H. Taylor and De Witt C. Webb were elected members, and Mr. Heber B. Clewley an associate of the Society.

Mr. Fred. Brooks, for the Committee appointed to prepare a memoir of Willis H. Hall, submitted its report, which was read and accepted.

The Chairman announced the death of Horace L. Eaton, a member of the Society, which occurred on November 23, 1895, and on motion the President was requested to appoint a committee to prepare a memoir.

The thanks of the Society were voted to the Walworth Manufacturing Co., of Boston, for courtesies shown its members on the occasion of the visit to the Company's works at South Boston this afternoon.

The following resolution, which was considered at the last meeting, came before the Society for adoption:

Resolved, That the Boston Society of Civil Engineers earnestly deprecate the use of any of the wire and sheet metal, or other trade gauges now in vogue, and strongly urge the use of a decimal system for all such measurements.

Mr. A. H. Howland spoke very strongly in opposition to the resolution. Upon a vote being taken, eighteen were in favor of its adoption and two against.

Mr. George S. Rice then delivered an informal address entitled "Some Notes Concerning the New Croton Aqueduct." Mr. Rice gave a general description of the work, illustrating the important features by over 100 lantern views, and spoke in more detail of the method of grouting which was used where defective work was discovered in the aqueduct.

Adjourned. S. A. TINKHAM, *Secretary.*

Willis H. Hall.—A Memoir.

BY FREDERICK BROOKS, A. M. MATTICE AND F. W. DEAN, COMMITTEE OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read December 18, 1895.]

WILLIS H. HALL, son of Edward B. and Ellen N. Hall, was born December 23, 1860, at West Westminster, Vermont. His ancestors had long lived in New England and had been engaged in farming. His education, after leaving the common school, was obtained at the Vermont Academy, at Saxton's River, Vermont, near his home, and at the Polytechnic Institute, at Worcester, Mass., where he studied for about a year. He was employed for a time at Hopedale, Mass., but his principal occupation was in the office of E. D. Leavitt, at Cambridgeport, where he was employed as draughtsman from September 5, 1882, to September 1, 1888, and again from December 28, 1891, to June 2, 1894. He also did some professional work in San Francisco, having gone to California to get the benefit of a mild climate. The latter part of his life was a continued struggle with that prevalent disease of New England, pulmonary consumption, of which he died at Fresno, California, August 26, 1895.

In his professional work he was conscientious, thorough and intelligent, always wanting to know the reason why. He was obliging and agreeable in all his intercourse, and his sterling character might be a worthy example for us all, though his life was without exciting incidents and was brought prematurely to a close.

In November, 1887, he married Miss Elmira F. Cobb, of Cambridge, Mass., who survives him.

Engineers' Club of Minneapolis.

MINNEAPOLIS, Minn., December 23, 1895.—A meeting of the Engineers' Club of Minneapolis was held at the office of the City Engineer, City Hall, at 8 P.M., the President in the chair.

Minutes of previous meetings were read and approved, after correcting those of last meeting relating to statement of indebtedness, making them read "which sum was entirely a balance due to the JOURNAL."

A statement was again made of the account due for the JOURNAL, of the money on hand, and the amounts due the Club from its members, after informal discussion.

W. R. Hoag moved that the Secretary and Treasurer be instructed to send to J. C. Trautwine, Jr., Secretary of the Association of Engineering Societies, Seventy-five Dollars ($75) and to notify him that the balance of the amount already due would be send him by February 1, 1896.

That from January 1, 1896 (for the JOURNAL of 1896), a new mailing list will be furnished, and that Mr. Trautwine be instructed to send no JOURNALS on account of this Club, to any one not upon the new list.

That the Secretary place no name on the new list until the money is paid him for the JOURNAL of 1896. Carried unanimously.

It was then moved that the Secretary be instructed to see all the members of the Club before January 1, 1896, and ask them to take the JOURNAL and pay him the Three Dollars ($3) in advance, or send in their resignations, or the Club will take suitable action at its next meeting. Carried.

G. D. Shepardson moved that an assessment of Three Dollars ($3) be levied on each member of the Club to apply on the JOURNAL for 1896. Carried.

On motion adjourned to meet in January, as the annual meeting to elect officers.

ELBERT NEXEN, *Secretary.*

Bradley & Poates, Engr's, N.Y.

INDEX TO CURRENT LITERATURE.

NOTICE.

Notice is hereby given to the readers of this Journal that after the completion of the current volume, with the December number, 1895, this Index Department will be discontinued. This action has been taken by the Board of Managers of the JOURNAL in view of the elaborate and more complete index to current engineering and other technical literature, which is now published in the *Engineering Magazine.* The JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES has maintained this Index Department for the past eleven years at an annual expense for composition, printing and republication in the annual summary, of about $1,000. This Index has been entirely unique in its characteristics, but within the last few months the Index published by the *Engineering Magazine* has been prepared directly on the lines which have been followed in the preparation of our own Index Department. Since the editor of that journal proposes to maintain his Index on these lines, and to publish an annual summary as a separate volume, which will be sold separately from the *Magazine*, the Board of Managers of this journal has decided to abandon the work, and to recommend the readers of this journal who value the Index Department to subscribe for the *Engineering Magazine*, and so encourage the editor of that journal to maintain this department in an adequate manner.

The editor of that magazine has also agreed to republish the index notes which have appeared in this journal for the last four years in a bound volume, similar to that published some years ago, containing the index notes for the seven preceding years.

In thus taking leave of the many friends who have encouraged the manager of this department in the past, by their appreciative recognition of the service rendered them in its preparation, he bespeaks for the editor of the *Engineering Magazine* the same kind consideration and helpful assistance.

J. B. JOHNSON,
Manager Index Department, Chairman Board of Managers.

THE repetition of titles in this issue of the annual index in place of the use of dashes, as heretofore, is due to the use of the linotype machine in setting the type. By its use the total cost of the index has been reduced about one-third.

LIST OF PERIODICALS INDEXED.

Following the title of each periodical is given, in italics, the abbreviation by which it is referred to in the Index.

For alphabetical list of abbreviated titles, see page iv.

UNITED STATES.

ANNUAL.

American Institute of Mining Engineers, Transactions of the — (*Trans. A. I. M. E.*), 13 Burling Slip, New York; per year, $5.

American Society of Mechanical Engineers, Transactions of the — (*Trans. A. S. M. E.*), 12 West Thirty-first Street, New York.

American Water Works Association, Proceedings of Annual Meetings of the — (*Am. W. W. Ass'n.*), 95 William Street, New York; per year, $1.

Society of Naval Architects and Marine Engineers, Transactions of the—(*Trans. N. A. & M. E.*), W. L. Capps, Secretary, 1710 F Street N. W., Washington, D. C.; $10 per annual volume.

QUARTERLY.

Engineers' Club of Philadelphia, Proceedings of the — (*Proc. Eng. Club Phila.*), 1122 Girard Street, Philadelphia, Pa.; per year, $2.

New England Water Work Association, Journal of the —(*Jour. N. E. W. W. Assn.*), New London, Conn.; per year, $2; single copies, 75 cents.

School of Mines Quarterly (*Sch. Mines Quart.*), Columbia College, New York City; per year, $2; single copy, 50 cents.

Technology Quarterly and Proceedings of the Society of Arts (*Tech. Quart.*), Massachusetts Institute of Technology, Boston, Mass.; per year, $3.

United States Naval Institute, Proceedings of the —(*Proc. U. S. N. I.*), United States Naval Institute, Annapolis, Md.; per year, $3.50; single copy, $1.

MONTHLY.

Societies.

American Institute of Electrical Engineers, Transactions o the — (*Trans. A I. E. E.*), 12 West Thirty-first Street, New York City.

American Society of Civil Engineers, Transactions of the — (*Trans. A. S. C. E.*), 127 East Twenty-third Street, New York ; per year, $10.

Association of Engineering Societies, Journal of the — (*Jour. Assn. Eng. Socs.*), Philadelphia ; per year $3 ; single copy, 30 cents.

Engineers' Society of Western Pennsylvania, Proceedings of—(*Proc. Eng. Soc. W. Pa.*), Allegheny, Pa ; per year, $7 ; single copy, 75 cents.

Franklin Institute, Journal of the — (*Jour. Frank. Inst.*), Franklin Institute, Philadelphia, Pa.; per year, $5; single copy, 50 cents.

Periodicals.

American Engineer and Railroad Journal (*Am. Eng. & R. R. Jour.*), 47 Cedar Street, New York ; per year, $3 ; single copy, 25 cents.

Cassier's Magazine (*Cassier*), World Building, New York ; per year, $3; single copy, 25 cents.

Clay Worker (*Clay W.*), Indianapolis, Ind.; per year, $2.00.

Engineering Magazine (*Eng. Mag.*), 47 Times Building, New York; per year, $3; single copy, 25 cents.

Engineering Mechanics (*Eng. Mech.*), 430 Walnut Street, Philadelphia, Pa.; per year, $1 ; single copy, 10 cents.

Irrigation Age (*Irrigation Age*), Chicago, Ill.; per year, $2.

Master Steam Fitter (*Mst. Stm. Fitter*), 218 La Salle Street, Chicago, Ill. ; per year, $1 ; single copy, 10 cents.

Municipality and County. The — (*Munic & Co.*) Niagara Publishing Co., 202 Main St., Buffalo, N. Y.; per year, $2.

Paving and Municipal Engineering (*Pav. & Munic. Eng.*), Municipal Engineering Co., 44 Chamber of Commerce, Indianapolis, Ind.; per year, $2; single copy, 25 cents.

Power (*Power*), World Building, New York ; per year, $1 ; single copy, 10 cents.

Railway Engineering and Mechanics (*Ry. E. & M.*), 816 The Rookery, Chicago, Ill.; per year, $1 ; single copy, 10 cents.

Safety Valve (*Sy. Valve*), 55 Liberty Street, New York; per year, $1 ; single copy, 10 cents.

Street Railway Journal (*St. Ry. Jour.*), World Building, New York; per year, $4 ; single copy, 35 cents.

Stone (*Stone*), Chicago; per year, $2 ; single copy, 25 cents.

Street Railway Review (*St. Ry. Rev.*), 269 Dearborn Street, Chicago, Ill.; per year, $2 ; single copy, 25 cents.

WEEKLY.

American Architect (*Am. Arch.*), Ticknor & Co.; 211 Tremont Street, Boston, Mass.; single copy, 15 cents.

American Machinist (*Am. Mach.*), 96 Fulton Street, New York; per year, $2 ; single copy, 10 cents.

Boston Journal of Commerce (*Bos. Jour. Com.*), 128 Purchase Street, Boston, Mass.; per year, $3; single copy, 6 cents.

Electrical Engineer (*Elec. Engr.*), 203 Broadway, New York ; per year, $3.

Electrical World (*Elec. World*), 177 Times Building, New York; per year, $3 ; single copy, 10 cents.

Engineering and Mining Journal (*E. & M. Journal*), 253 Broadway, New York; per year, $5 ; single copy, 15 cents.

Engineering News (*Eng. News*), Tribune Building, New York; per year, $5; single copy, 15 cents.

Engineering Record (*Eng. Rec.*), 277 Pearl Street, New York; per year, $5 ; single copy, 12 cents.

Railroad Gazette (*R. R. Gaz.*), 32 Park Place, New York ; per year, $4.20 ; single copy, 10 cents.

Scientific American Supplement (*Sci. Am. Sup.*), 361 Broadway, New York; per year, $5; single copy, 10 cents.

Electric Railway Gazette (*Elec. Ry. Gaz.*), Monadnock Block, Chicago ; per year, $3; single copy, 25 cents.

CANADA.

Canadian Society of Civil Engineers, Transactions of the — (*Trans. Can. Soc. C. E.*), McGill University, Montreal.

GREAT BRITAIN.

Electrical Review (*Elec. Rev.*), 22 Paternoster Row, London, E. C.; weekly; per year, 21s, 8d; single copy, 4d.

Engineer, The — (*Lon. Engineer*), London, England; weekly; per year, $10; single copy, 25 cents.

Engineering (*Lon. Eng.*), London, England; weekly; per year, $10; single copy, 25 cents.

Engineering Review (*Eng. Rev.*), 29 Great George Street, S. W., England; monthly; single copy, 6d.

Institution of Civil Engineers, Proceedings of the — (*Proc. Inst. C. E.*), 25 Great George Street, Westminster, S. W., London, England.

Institution of Mechanical Engineers, Proceedings of the — (*Proc. Inst. Mech. Engs.*), 19 Victoria Street, Westminster, S. W., London, England.

Mechanical World (*Mech. World*), Manchester, England; weekly; per year, 8s, 8d.

Practical Engineer (*Prac. Engr.*), 2 Amen Corner, London, E. C., England; weekly; pei year, 10s.

Railway Engineer (*Ry. Eng.*), 8 Catherine Street, Strand, W. C., London, England; monthly; single copy, 1s.

INDIA.

Indian Engineer (*Ind. Engr.*), Calcutta, India; per year, 20 Rs.

Indian Engineering (*Ind. Engng.*), Calcutta, India, weekly; per year, 18s; single copy, 8 annas.

FRANCE.

Ponts et Chaussées, Annales des — (*Annales des P. & C.*), monthly. Vve. Ch. Dunod, 49 Quai des Augustins, Paris, France.

Société des Ingénieurs Civils, Mémoires de la — (*Mems. Soc. Ing. Civils*), monthly, 10 Cité Rougement, Paris.

GERMANY, AUSTRIA AND SWITZERLAND.

Archiv für Eisenbahnwesen (*Arch. f. Eisenbw.*), bi-monthly, Julius Springer, Berlin, Germany; per year, 12 marks.

Civilingenieur, Der — (*Civ. Ing.*), monthly.

Deutsche Bauzeitung (*Deutsche Bztg.*), semi-weekly, Berlin, Germany; per year, 12 marks.

Journal für Gasbeleuchtung und Wasserversorgung (*Jour. f. Gasb. u. Wasserv.*), three times a month, 11 Glückstrasse, Munich, Germany; per year, 20 marks.

Praktische Maschinen-Constructeur, Der—(*Pr. Msch. Cnstr.*), bi-weekly, Leipzig-Gohlis, Germany; per year, 16 marks.

Schweizerische Bauzeitung (*Schw. Bztg.*), German and French, 32 Brandschenkestrasse, Zurich.

Zeitschrift des Oesterreichischen Ingenieur und Architekten Vereins (*Ztsch. Oest.*), weekly.

Zeitschrift des Vereines Deutscher Ingenieure (*Ztsch. Ver. Ing.*), weekly, Berlin, Germany; per year, 32 marks.

For alphabetical list of abbreviated titles, see page iv.

Alphabetical List of Abbreviated Titles

OF PERIODICALS INDEXED.

For list of full titles, see page i.

Am Arch. *American Architect*, Boston; weekly.
Am Eng & R R Jour. *American Engineer & Railroad Journal*, New York; monthly.
Am Mach. *American Machinist*, New York; weekly.
Am. W. W. Assn. *Proceedings, American Water Works Association*, New York; annual.
Annales des P & C. *Annales des Ponts et Chaussées*, Paris, France; monthly.
Arch f Eisenbw. *Archiv für Eisenbahnwesen*, Berlin, Germany; bi-monthly.
Bos. Jour. Com. *Boston Journal of Commerce*, Boston, Mass.; weekly.
Cassier. *Cassier's Magazine*, New York; monthly.
Civ Ing. *Der Civilingenieur;* monthly.
Clay W. *Clay Worker*, Indianapolis, Ind.; monthly.
Deutsche Bztg. *Deutsche Bauzeitung*, Berlin, Germany; semi-weekly.
E & M Journal. *Engineering and Mining Journal*, New York; weekly.
Elec Eng. *The Electrical Engineer*, New York; weekly.
Elec Rev. *Electrical Review*, London, Eng.; weekly.
Elec World. *The Electrical World*, New York; weekly.
Eng Mag. *The Engineering Magazine*, New York; monthly.
Eng Mech. *Engineering Mechanics*, Philadelphia, Pa.; monthly.
Eng News. *Engineering News*, New York; weekly.
Eng Rec. *Engineering Record*, New York; weekly.
Eng Rev. *Engineering Review*, London, Eng.; monthly.
Ind Engng. *Indian Engineering*, Calcutta, India; weekly.
Ind. Engr. *Indian Engineer*, Calcutta, India; weekly.
Irrigation Age. *The Irrigation Age*, Chicago, Ill.; monthly.
Jour Assn Eng Socs. *Journal of the Association of Engineering Societies*, Philadelphia; monthly.
Jour f Gasb u Wasserv. *Journal für Gasbeleuchtung und Wasserversorgung*, Munich, Germany; three times a month.
Jour Frank Inst. *Journal of the Franklin Institute*, Philadelphia, Pa.; monthly.
Jour N E W W Assn. *Journal of the New England Water Work Association*, New London, Conn. quarterly.
Lon Eng. *Engineering*, London, England; weekly.
Lon Engineer. *The Engineer*, London, England; weekly.
Mst. Stm. Fitter. *Master Steam Fitter*, Chicago, Ill.; monthly.
Mech World. *The Mechanical World*, Manchester, England; weekly.
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Munic & Co. *Municipality and County, The*——, Buffalo, N. Y.; monthly.
Pav & Munic Eng. *Paving and Municipal Engineering*, Indianapolis, Ind.; monthly.
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Pr Msch Cnstr. *Der Praktische Maschinen-Constructeur*, Leipsic.
Prac. Engr. *Practical Engineer*, London; weekly.
Proc Eng Club Phila. *Proceedings of the Engineers' Club of Philadelphia*, Philadelphia, Pa.; quarterly.
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Proc Inst Mech Engrs. *Proceedings of the Institution of Mechanical Engineers*, London, England.
Proc U S N I. *Proceedings of the United States Naval Institute*, Annapolis, Md.; quarterly.
R R Gaz. *Railroad Gazette*, New York; weekly.
Ry E & M. *Railway Engineering and Mechanics*, Chicago, Ill.; monthly.
Ry Eng. *The Railway Engineer*, London, England; monthly.
Sch Mines Quart. *School of Mines Quarterly*, New York City.
Schw Bztg. *Schweizerische Bauzeitung*, Zurich; German and French; weekly.
Sci Am Sup. *Scientific American Supplement*, New York; weekly,
Stone. *Stone*, Chicago, Ill.; monthly.
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St Ry Jour. *Street Railway Journal*, New York; monthly.
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